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LEVIN

Infantile

In this fine book on Infantile Paralysis all its phases—from history to treatment—Dr. Lewin's work is meticulous in detail and unsurpassed in authority.

Dr. Lewin tells how to recognize Infantile Paralysis and gives in precise detail the treatment.

Each phase of the subject is covered: Etiologic, virologic, epidemiologic, therapeutic, orthopedic, surgical, sociologic and considerations of the early diagnostic differentiation of the causative virus, modes of transmission, causes, prophylaxis, prevention. He defines for the doctor what to do and what not to do with poliomyelitis as well as with one that has become chronic.

Operative and nonoperative technique and description of methods stated. Separate chapters are devoted to operations on the upper extremity, spine, neck, hip, the knee region, foot and ankle. Nursing, step-by-step technique. Physical therapy and chronic stages is discussed, and there is a complete use of braces.

Throughout this book the author gives close importance of proper nursing care of paralysis patients as part of the management of every case.

With the constantly growing interest in Infantile Paralysis, Dr. Lewin's book is a

Infantile Paralysis. By Peter

166 illustrations.

W. B.

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CONTENTS

SYMPOSIUM ON SURGICAL INFECTIONS

	P g
Introd ct	317
By Dr Frank L. Meloney	
Surg l B cte logy	319
By Dr Frank L. Meloney	
St l at	333
By Dr Carl W. Walter	
M m g the Co tam n t f Operat W ds	357
By Dr Deryl Hart	
Accd t l W u d l f e t o n	377
By Dr Alfred B. Longacre	
I f c t n s f Sk n a d S b c t o s Tissue	399
By Dr Harold D. Harvey	
I f c t n of th Che t	415
By Dr Roy D. McClure	
S rg c l Inf t of th P r t u m	437
By Dr William A. Altemeier	
I f t n of th Ha d	455
By Dr Michael I. Mison	
Th Chem the py f S g al I f c t s	479
By Drs Frank L. Meloney and John S. Lockwood	
Imm ol g al Asp ts f S g al I f c t s	501
By Dr Champ Lyons	

CLINICS ON OTHER SUBJECTS

The I d st l B ck Probl m	515
By Dr Irvin Balensweig	
C ge t l D lo cat of the Hp	553
By Dr Arthur Krda	

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CONTENTS

SYMPOSIUM ON SURGICAL INFECTIONS

	P g
Introduct	317
By Dr Frank L. Meloney	
Surgical Bacteriology	319
By Dr Frank L. Meloney	
Stellaton	333
By Dr Carl W. Walter	
Minimizing the Complications of Operative Wounds	357
By Dr Deryl Hart	
Accidental Wound Infections	377
By Dr Alfred B. Longacre	
Infections of Skin and Subcutaneous Tissue	399
By Dr Harold D. Harvey	
Infections of the Chest	415
By Dr Roy D. McClure	
Self-Infections of the Peritoneum	437
By Dr William A. Altemeier	
Infections of the Head	455
By Dr Michael L. Mason	
The Chemotherapy of Surgical Infections	479
By Drs Frank L. Meloney and John S. Lockwood	
Immunologic Aspects of Surgical Infections	501
By Dr Champ Lyons	

CLINICS ON OTHER SUBJECTS

Thrombotic Back Pain	515
By Dr Irvin Balensky et al	
Congenital Dislocation of the Hip	553
By Dr Arthur Krida	

CONTENTS

Th P s t St t f th S g l T tm t f B d J t	P
T be c l s	565
By Dr Irvan Balens	or
Th T atme t f Ch c Ost my lts	581
By Dr Joseph B chman	
Ap s O l p f th C f l g l H	597
By Drs Henry F Graham nd Edw r O Mart ns n	
Th U f X R dat A lg c Ag t	601
By Dr John Russell C rty	
Sc l A t Sy d m	611
By Dr H G Ha ss n	
P m ry a d S c d ry (R l) Hyp p thy d sm	621
By Dr Henry L Jaffe	
C m l t l d	641

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SYMPOSIUM ON SURGICAL INFECTIONS

INTRODUCTION

WHEN this Symposium on Surgical Infections was planned the collaborators were selected because of their recognized experience in their respective fields. With the advent of America's entry into the war each one of them was drawn into close identification with the plans for national defense. It is hoped that the papers in this symposium will serve the purpose of stimulating interest in the subject of surgical infections which has become of vital importance with the occurrence of war.

The Editor does not necessarily agree with all of the opinions expressed by the different collaborators but he can vouch for the fact that in each instance the contribution is based on wide experience and honest opinion.

FRANK L. MELENBY, M.D.

SURGICAL BACTERIOLOGY

FRANK L MELENEY MD FACS†

Many people do not realize how completely modern surgery depends upon the science of bacteriology. They grew up together. Before it was demonstrated that surgical infections were due to the activity of micro organisms and that they could be kept out of operative wounds by proper control of the conditions of operations surgery was limited in its scope to the removal of superficial growths and the care of accidental wounds. Even these relatively simple procedures were handicapped by a high incidence of infection and death. In those days hospital surgery was infinitely more precarious than home surgery because infection spread so rapidly from one patient to another. Any attempt to perform operations within the body cavities was almost certain to seal a death warrant from infection and the attempt was rarely made.

Following the discoveries of Pasteur and their application to surgery by Lister there gradually evolved the operating room procedures designed to prevent the entrance of bacteria into the operative wound which has come to be known as sterile technic. This marked the beginning of a great epoch in surgery and along with the development of anesthetics opened up the field of surgery to permit safe explorations into the innermost recesses of the body. It required from the surgeon a much clearer and more extensive knowledge of anatomy and a longer training in the technic of surgical procedures. Surgeons went at this wildly and in doing so forgot all about bacteriology and what the science had done for them. They took it for granted and turned their attention to

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more interesting problems involved in the perfection of operative procedures. It is true that not infrequently something would go wrong and infection would nullify their best efforts, but for the most part they were satisfied with the results obtained.

With the accumulation of facts and figures and the frequent repetition of results we have recently entered into a period in which greater efforts are being made to minimize the risks of operation among which is the ever present risk of infection. Furthermore the growing frequency of accidents, caused by the ever increasing speed of movement in our highly mechanized environment has increased the chances of disability or death from infection. And lastly, the recurrence of war on a more extensive and more devastating scale than ever before with burns and blast and crushing injuries added to the horrors of bullet and shrapnel and shell fragment wounds make the subject of surgical infections a particularly timely one just now.

The author's first interest in infections came during his junior internship when he was persuaded by his house surgeon Dr Guy Caldwell now of Tulane University to carry out a study of the effect of operation on the leukocyte count in noninfected cases. The study showed that within six hours of the operation the leukocyte count almost invariably doubled but in cases which remained clean it returned to normal in four days. The totally unexpected result of the study was that about 10 per cent of these clean cases became infected and the white count remained elevated for ten days or more. Before the cause of the clean wound infections could be investigated the author was called into the Army.

In the Army service infection of war wound made a great impression on me. We left the United States on July 4 and landed in France on Bastille Day, July 14. It was a black day for France. Then the Chateau Thierry counteroffensive began. Our mobile operating unit was broken up into operating teams of three surgeons, two corps men and a nurse and rushed to the front. The casualties greatly exceeded expectations as the Americans reached out for new objectives. When our team got to the front we were assigned temporarily to a

field hospital behind the First and Second Divisions. There were 250 wounded men on stretchers out under the trees waiting for an evacuation hospital to be put up in which they might be operated upon and cared for. Bassoneau tents went up in a hurry. I will never forget some of the cases that came under my care at that time and during the later offensives. Nor shall I forget the swarm of flies on the ceiling of the operating tent in that first hospital. The thoughtless proximity of litchens and latrines to the unscreened operating tent was undoubtedly a factor in the incidence of infections there. One of the first patients had thirty-two superficial wounds from shell fragments. And there was a fine young lad who had survived the initial onslaught and had come back for a re-t period. He was cleaning his revolver when it went off and the bullet passed through his posterior tibial artery and produced a huge hematoma. We tried to save the leg but gas gangrene developed and we had to amputate.

Another case made a great impression on me. The patient had been shot through the thigh, scrotum and groin. Omentum was protruding through a hernial opening and hanging down between the thighs. The wound was alive with maggots. We washed them with soap and water but they enjoyed the bath. We finally had to anesthetize them with ether and the wound then looked surprisingly clean. The maggots had consumed all the slough and pus. The omentum was amputated and the stump replaced in the abdominal cavity and the wound then healed with unusual rapidity. One boy had when he came to us very extensive gas gangrene of the abdominal wall. This required the excision of all of the external oblique and the internal oblique muscles on one side. Only the transversalis remained. The infection then came under control and we heard later of his complete recovery. A similar case but more extensive was beyond control—a fractured pelvis and femur with gas spreading down the thigh and up the flank to the chest—across the abdomen beyond the midline. We made long incisions but when we found the extent of invasion we gave it up as hopeless.

Three men came in from the Lost Battalion which had been surrounded by Germans and cut off for six days with no

medical officer or medical supplies. One of them was dying of peritonitis. His abdomen was puffed up like a balloon fish. I put in a metal tube to let out the gas and thus ease his last few hours. The others had tetanus. One was moribund. The other came to our operating table. He was a Montana cowboy and the bravest hero I have ever met. The corners of his mouth were drawn back in that grin of death which is such a mockery in that dread disease. He told us about the days of isolation how brave Major Whittlesey was and every other man. No word of complaint crossed his lips although he was terribly wounded—in the left foot which was gangrenous in the left calf where there was a through and through wound so old that a mold was growing on the surfaces in the left forearm where there was a compound fracture of the radius in the left pectoral region where there was a large amount of macerated muscle and in the right leg where the wound was superficial. I asked him if he was in great pain. He answered: No not much. I'd be all right exceptin' for my jaw which seems to be pretty tight. You don't suppose its lockjaw do yer?

Oh no. I said we'll give you some medicine and fix that up for you.

We told him that we would have to take off his gangrenous foot. All right go ahead. You know best. His confidence was complete. We worked rapidly. My team mates on the arm and shoulder. I on the foot and leg. In spite of speed however his respirations became slow and shallow. After the operation we stimulated him with oxygen until our commanding officer said: I know you want to save the boy but I think you had better save the oxygen for some one whom it will help more. We only have a limited supply. He must die any way. There is no hope. But he lived for three days after that. I pumped tetanus antitoxin into his muscles and spinal canal with no effect. I dreaded the final convulsions. His jaw became tighter and tighter until every tooth ached. I'd be all right if you could only loosen up my jaw. That was his only complaint and this was said without tears or bitterness. The convulsions never came. The respiratory apparatus became

affected first and he died peacefully thank God! The great est hero of my war experience—Private Leonard Tudor #3 129 826 Company H 308th Infantry

Many times we found ourselves helpless in the face of established infection or defeated by the development of it after debridement. Our best efforts often seemed utterly futile. These boys were broken open in a moment of time and we spent countless hours trying to patch them again only to lose them by infection.

On my return from France I conferred with my friend and advisor Dr. Whipple with regard to my further training in surgery and he made this significant statement and prophecy.

In the past surgeons have been anatomists. Now some of them are trying to be pathologists but the surgeons of the future will be physiologists, chemists or bacteriologists. Which do you want to be? My interest in infection aroused in France led me to choose bacteriology. Fortunately Dr. Zinsser, then Professor of Bacteriology at Columbia, was sympathetic to the idea which he had had for some time of trying to train a surgeon in bacteriology because he felt that the two departments should be more closely associated.

The initiation of the plan was postponed during a period of service in China but in 1925 a *bacteriological research laboratory* to serve as a link between the Departments of Surgery and Bacteriology in the College of Physicians and Surgeons, New York City, was established. Problems immediately presented themselves. To illustrate a few only. In 1925 we were faced with the problem of finding the cause of a series of hemolytic streptococcus wound infections in clean cases and traced it by careful *cross absorption of agglutinin tests* to the unmasked nose of an operating room nurse, thus proving conclusively what had been suspected for some time—that *complete masking* is important in sterile technique. This study not only led to *masking* but to a careful checking of all operating room technique and the initiation of a continuous survey of wound infections with a gradual closing of doors to all sources of bacterial contamination. The surgical

staff has become bacteria conscious and technique has gradually improved so that our incidence of wound infections has fallen from 15 per cent to 2 per cent in the last fifteen years.

The careful study of a fatal case of infection of the abdominal wall in another hospital led to the discovery of a new pathogenic anaerobe of the gas gangrene series. Priority of discovery, however, goes to Sordelli who two years earlier found a similar organism in Buenos Aires. The source of the infection in the patient observed by us was traced to the same batch of catgut used in that case and in four other fatal cases in a single week. This led to a study of *catgut sterility* and the development of an adequate test for sterility. There has been a gradual improvement in the sterility of catgut and the standard set up by the United States Pharmacopoeia is now being maintained under the new Pure Food and Drugs Act administered by the Food and Drugs Administration.

Later a peculiar type of progressive gangrenous ulcer of the abdominal wall following the drainage of a peritoneal or pleural abscess was studied and found to be an example of *bacterial synergism*. Still later another infection characterized by chronic ulceration with extensive undermining of the skin, involvement of lymphatic glands and erosion of blood vessels came under careful scrutiny and both the cause and a remedy were found.

The problems which presented themselves were legion and only the surface has been scratched. Many problems still await careful study and solution.

SURGICAL INFECTIONS

Surgical infections as distinguished from medical infections are primarily *local* with local collection of exudate or local destruction of tissue. They deal with a fairly limited number of organisms which we call *pyogenic* or *necrotizing*. They produce inflammations which usually do not spontaneously resolve and while they may and frequently do spread extensively about the body they tend to form foci of infection rather than diffuse processes. While problems of immunity come into the realm of surgical bacteriology, they are more often problems of local than of general resistance to

disease. The organisms causing surgical infections are in general those which do not produce any immunity in the host in the usual sense. However it is well recognized that individuals differ in susceptibility to surgical infections and the problems of determining the nature of this resistance or measuring it or augmenting it are still awaiting solution.

Surgical infections may be divided into four groups according to the *time* of bacterial contamination or invasion. Bacteria may get into the body (1) long before or (2) just before the patient comes to the surgeon. They may also get into the patient (3) at the time of operation or (4) subsequently. There are problems to be solved in each of these four categories.

I. Long established infections

In the first group we have such problems as lung abscess, ulcerations of the skin and of the alimentary tract, brain, liver and kidney abscess, cholecystitis and osteomyelitis. The osteomyelitis of children is a particularly intriguing problem because the organisms frequently get in through a portal of entry which is not apparent and find especially favorable surroundings for growth in certain parts of bone.

The *synergism* and *antagonism* of bacteria in the production of human infection open up a large field of investigation which has hardly been touched and which awaits the time and energy of a number of keen surgical bacteriologists. Wherever mixtures of bacteria are found in lung abscess, in bronchiectasis, in mouth and neck infections, in infections all along the alimentary tract and in the peritoneal cavity, as well as in traumatic wounds, both accidental and the intentional wounds.

For the problem of the synergism and antagonism of bacteria presents itself and cries out for elucidation. Research in the antagonism of bacteria has recently borne fruit in the discovery by Dubois of *gramicidin* which is an extract of a pure fermenting soil bacterium which has the power to kill all gram positive organisms when brought in local contact but which is impotent against the gram negative organisms and is toxic for animals when used generally. Similarly the discovery by Fleming of *penicillin* a product of the mold *Penicillium*

which has a similar action in extraordinarily minute doses is wider in its range of activity and seems to be nontoxic to human tissues. More extensive studies with these products should be carried forward.

2. Infectious Accidental Wounds

Growing Extent of Problem in Peacetime—The increased speed with which man travels at the present day, the complicated machinery which he is required to operate and the increasing violence to which man is subject in this present conflict has brought us face to face with the growing problem of what to do to prevent infection by organisms which have been introduced into the body just before the patient comes to the surgeon.

Even in peacetime the problem of infection in accidental wounds has been steadily growing because of the increase in the mechanization of our existence and the increased speed of our movements. It is true that in industry safety devices have been provided but compensation laws have removed from the mind of the worker the necessity of extreme caution. He is willing to take chances and by the law of chance a certain number of individuals must be expected to suffer. The increased speed of air travel and the increasing numbers of people involved have increased a potential danger with which safety devices have not kept pace and the competition with the airplane has necessitated greater speeds in train and automobile travel for which roadbeds and roads are not completely adequate.

Accidents resulting from high speed produce injuries to the human body that differ from those produced a generation ago chiefly due to the increased momentum of the moving object. This may produce injury to deep tissues or be transmitted from the site of contact to distant parts of the body. The chief importance of modern accidents however is due to the great number of people involved and consequently the greater variety of injuries that are incurred.

War Injuries—The steadily growing importance of civilian peacetime accidents is now greatly augmented by the countless numbers of people injured by this cataclysm of war. The in-

creasing numbers and range of the airplane has spread devastation and death over wide areas so that added to the problems of gunshot wounds which faced us in the last war we have the victims of the blast of bombs and the crushing effects of falling masonry. It is true that there is a high incidence of immediate death in which there is no problem of infection but in those which survive the shock of the injury the question of whether they live or die whether they are restored to normal living or are permanently handicapped or incapacitated depends largely on whether or not infection develops from the organisms which are introduced at the time of the injury or subsequently enter during the course of wound healing.

This is the major problem today which has been forced upon us by the advent of war and has temporarily eclipsed all other problems in surgical bacteriology.

The Use of Antiseptics—Experience in the last war emphasized the importance of removing the damaged tissue and foreign bodies from gunshot wounds and in addition the majority opinion favored the use of an antiseptic *Dakin's solution* which had a moderate bactericidal and bacteriostatic action but also had the advantageous property of liquefying dead tissue. It had the disadvantage of being very transient in its action and therefore requiring frequent renewal and it was found to inhibit or delay the process of wound healing. Furthermore it was unstable and if not used in a fresh state was often irritating to the wound. During the twenty years interval of peace therefore in many clinics *Dakin's solution* has largely dropped out of use and at a panel discussion at a meeting of the American College of Surgeons in Philadelphia in 1938 it was the consensus of the surgeons in the panel that the fundamental purpose in the treatment of accidental contaminated wounds or war wounds was to change a dirty wound into a clean wound by washing, excising damaged tissue and removing foreign bodies. They agreed that such wound might then be closed if early or left open if late. It was their expressed opinion that very little consideration need be given to the bacterial flora and that bactericidal or bacteriostatic agents did more harm than good.

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This is the major problem today which has been forced upon us by the advent of war and has temporarily eclipsed all other problems in surgical bacteriology.

The Use of Antiseptics—Experience in the last war emphasized the importance of removing the damaged tissue and foreign bodies from gunshot wounds and in addition the majority opinion favored the use of an antiseptic *Dakin's solution* which had a moderate bactericidal and bacteriostatic action but also had the advantageous property of liquefying dead tissue. It had the disadvantage of being very transient in its action and therefore requiring frequent renewal and it was found to inhibit or delay the process of wound healing. Furthermore it was unstable and if not used in a fresh state was often irritating to the wound. During the twenty years interval of peace therefore in many clinics Dakin's solution has largely dropped out of use and at a panel discussion at a meeting of the American College of Surgeons in Philadelphia in 1938 it was the consensus of the surgeons in the panel that the fundamental purpose in the treatment of accidental contaminated wounds or war wounds was to change a dirty wound into a clean wound by washing excising damaged tissue and removing foreign bodies. They agreed that such a wound might then be closed if early or left open if late. It was their expressed opinion that very little consideration need be given to the bacterial flora and that bactericidal or bacteriostatic agents did no real harm than good.

From the floor of that panel meeting I tried to emphasize the importance of a careful study of the bacterial content of such wounds in order that the surgeon might know the potentiality of infection in that wound. Thus only may he avoid being caught unaware if infection develops. With that knowledge it is then the responsibility of the surgeon to do *everything he can* to prevent the activity of the organisms he knows to be present and it is also his responsibility to be on the lookout for the first signs of an infection. At that meeting I proposed that in addition to cleaning, debriding and resting the part in wounds over six hours old which could not be safely closed a new bactericidal agent (*in peroxide*) be used to destroy many of the organisms which are commonly found in contaminated wounds and to inhibit others. I stated that it was entirely nontoxic to the body as a whole, nonirritating to local tissues and noninhibiting to wound healing. At that time the sulfonamide drugs were just being heard from and no one had advocated their use in the prevention of wound infections. Sulfanilamide had been used successfully in puerperal fever and was just beginning to be used in other hemolytic streptococcus infections. The more recent derivatives had yet to be produced.

During the last two years great changes have taken place in the attitude of surgeons toward the local use of antiseptics. Little by little evidence has accumulated that the sulfonamide drugs as well as zinc peroxide may be used without much damage to the tissues.

It is not unlikely that the discovery of the new chemotherapeutic agents will mark the beginning of a new era in surgical infections. The virtual disappearance of hemolytic streptococcus septicemia in the last few years and the striking lowering of mortality in pneumonia meningitis and peritonitis are generally accredited to the extensive use of the *sulfonamide drugs*. We must however recognize the fundamental difference between medical and surgical infections—between the *diffuse inflammatory process* which does not destroy tissue but permits normal or increased circulation through the diseased organ which we classify as *medical* and the *localizing necrotizing suppurative process* which we classify as *surgical*.

In the one the newer chemotherapeutic agents are favored in the other they may be inhibited. This will be discussed in more detail in another section of this Symposium.

Status of Chemotherapy of Wounds—This whole question of chemotherapy in the prevention and treatment of infection in accidental wounds is in need of thorough investigation. Just now the issues are all confused. These drugs have been used indiscriminately by every one even the patients themselves and the literature is full of reports which are not reliable because they are based upon uncontrolled and therefore questionable observations. The gravest fault has been the totally inadequate study of the bacteriology of these wounds either before treatment began or during its course. It is only by knowing what organisms are present that we can know what organisms the drugs can control. Another grave fault is that in most reports the thoroughness of the surgical procedure is not indicated. Thorough cleansing and removal of damaged tissue and foreign bodies themselves minimize the number of organisms, lessen their chances for multiplication and favor the defense of the body. Such preliminary treatment will also favor the functioning of the chemotherapeutic agents. We must be able to compare cases receiving the same kind of surgical treatment with and without the addition of the medicinal agent in order to find out if it has any additional value.

A third serious fault in the reported studies has been the lack of detail with regard to the drug employed, the doses used and the method of administration. Well controlled studies have not yet been reported and as far as I know have not yet been done. It has not been possible to make controlled observations under the stress and strain of war in England where they have been overwhelmed by the numbers of casualties both in the Army particularly in the retreat from Dunkirk and in the civilian population.

Such a controlled study can be made in America by setting up units in various cities for the study of badly contaminated street and industrial accidents and burns. Such units would have to be fully equipped to make a complete bacteriological analysis of the wounds and follow them along with periodic

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agent which will act on the organisms normally contaminating the mucous membranes to permit operations on the alimentary tract with as little fear of wound infections as when we operate on the skin

4. Infect Subsequent to Operation

Finally we come to problems of surgical infection with respect to organisms which get into the body after the time of operation particularly during that period of disturbed physiology in which the normal barriers to the entrance of organisms are let down. The absence of the cough reflex under anesthesia which permits organisms to pass from the mouth into the lungs and the spasm of the sphincter of the bladder which retains urine and often demands catheterization permitting the entrance of organisms into a normally sterile cavity are examples of these postoperative infection requiring careful study.

Infections occasionally occur at the site of postoperative medication given either intravenously intramuscularly or subcutaneously and this involves the problem of sterile ward technique. Not infrequently wounds become secondarily contaminated at time of ward dressings and this may materially delay the wound healing. The spread of *Bacillus pyocyaneus* or the hemolytic streptococcus from patient to patient or from attendant to patient particularly with respect to burns presents a problem which should be seriously studied.

CONCLUSION

I let me close this brief review of the scope and possibilities of surgical bacteriology with a plea that surgeons everywhere recognize the debt they owe to bacteriology for what it has permitted them to do. I hope that they will also appreciate what it may still do for them if they will utilize it to the utmost.

Any hospital which does not have the proper bacteriological facilities and personnel trained to carry out routine and research studies properly with both aerobic and anaerobic techniques, will fall short of adequate service for its surgical department and must bear the responsibility for the death

cultures until the time of complete healing. They would have to be able to carry out standard surgical procedures and administer medicinal treatment according to a prescribed and prearranged plan with nondrug treated controls, cared for in precisely the same manner in other respects. Each unit would have to have a director to coordinate the work and keep scrupulously accurate and complete records of the nature and extent of the injury, the condition of the patient, the methods of treatment, the response to treatment, the clinical and laboratory evidence of infection, the speed and character of wound healing.

Such a careful study cannot be carried out in any one unit for more than a limited number of cases and there will be so many variable factors that they will have to be minimized by sheer weight of numbers. Therefore enough units must be set up to obtain data which will be statistically significant.

3.1. Factors in the Time of Operation

Problems of surgical infection with respect to organisms which get into the patient at the time of operation cover all of the minutiae of operating room technique. This to be effective must be constantly checked. One source of wound contamination must not be studied or controlled and the others neglected. Wound contamination from *all* sources must be reduced to a minimum. This is a perennial problem and year in and year out the most important problem in surgical bacteriology. We have not yet reached the irreducible minimum of wound infection. While sterility can be absolute with regard to solutions and dry goods which can be put in the autoclave and with respect to instruments which can be boiled (this will be covered in a later section) we still have to find agents which will kill bacteria on and in the skin of the hands and arms of the operating personnel and the skin of the patient in the field of operation. We must find foolproof impermeable masks to minimize contamination from the noses and mouths of the operating team and we must find a way to destroy the organisms present in the air of the operating room. The recent use of ultraviolet radiation may be the answer. We have yet to find a safe and adequate bactericidal

STERILIZATION

CARL W. WALTER, M.D.

THE basic facts and principles underlying aseptic technique merit repeated emphasis. The technique must coordinate the biophysical facts of sterilization with the needs of modern surgery. Standardization of technique whether in individual hospital or in the various hospitals in a community makes training of personnel easier and increases the convenience of those who must work in several hospitals. Striking economies in time, labor and materials result from proper use of well maintained equipment. Increased safety for the patient is the inevitable result of collaboration of the hospital staff in improving aseptic technique.

STERILIZATION BY MOIST HEAT

Physical Properties—Several factors have established saturated steam as the most reliable microbicide for the sterilization of textiles. Saturated steam is a physical entity with properties which are readily measured. Hence anyone can determine the microbiological quality of the steam in a sterilizer by reading a thermometer and a pressure gauge. The term saturated steam means that the steam exerts the maximum pressure for water vapor at the given temperature. The steam is therefore in a state lying on the boundary between two phases of aggregation—liquid and vapor. The shift from one state to the other entails a relatively large exchange of energy. In the range of temperature and pressure ordinarily used for sterilization

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or the cost of long hospitalization and disability of patients suffering from surgical infections. It is hoped that where such facilities are lacking the chief of surgery or the hospital trustees will demand fund for the equipment and running expenses for such a service. It will more than pay for itself in the saving of life and the shortening of hospitalization and disability. At the same time such laboratories may by some fortuitous circumstance together with effort and perseverance be able to make a contribution to the sum of medical knowledge that will be of inestimable value.

Lesser degrees of superheating are caused by putting *anhydrous fabric* into the sterilizer. Such fibers may adsorb as much as 2 per cent of their dry weight of water from the steam and liberate excess latent energy which superheats the textiles. The cumulative effect of superheating can be readily demonstrated. Identical samples of textile were sterilized simultaneously during the winter months when the humidity in heated rooms is low. The samples which were laundered (hydrated) immediately prior to sterilization lost 50 per cent of their tensile strength after seventy trips through the laundry and sterilizer whereas the samples which were sterilized repeatedly lost 73 per cent of their tensile strength.¹

It has long been recognized that *anhydrous greases or oils* decrease the lethal action of steam because they cover dry organisms and convert them into miniature dry heat ovens. The temperature used for steam sterilization is not high enough to be lethal in the absence of moisture.

The presence of *air* in a steam sterilizer retards or prevents sterilization in several ways. Air steam mixtures do not develop the temperatures characteristic of saturated steam under the same pressure hence killing power is decreased. The heating efficiency of air steam mixtures is also lower than that of saturated steam—a fact which is particularly important in the sterilization of instruments or solutions. Air reduces the penetrating power of steam because it prevents the convection of steam into bundles and liberation of latent energy in the depths of the bundle. In a sterilizer where air is present heating is principally by conduction. Because air and steam do not form stable mixtures except under adiabatic conditions air prevents steam from contacting bacteria and the bacteria which are protected by air escape destruction.

Air can be removed from the sterilizer easily by taking advantage of the fact that air is more dense than steam and stratifies below it. An outlet at the bottom of the sterilizer permits the air to escape by gravity² just as water flows out the drain of a bathtub. In a loaded sterilizer three factors may interfere with air clearance. First steam must have free access to packages to assure rapid dependable sterilization. The conventional sterilizing drums limit the surface of the package

54 calories of latent energy are liberated every time 1 gram of steam condenses. On contacting cold objects saturated steam condenses simultaneously heating and wetting them thereby providing both requisites for thermal destruction of bacterial life—moisture and heat.

Saturated steam penetrates textiles readily for two reasons. First steam is less dense than air hence does not mix with it readily and displaces the colder heavier air from the interstices of textiles by convection. Second abstraction of heat from steam causes a change in its state with an attendant 99 per cent decrease in volume. This volume collapse results in the instantaneous development of local areas of negative pressure which speed up convection. Steam thus carries energy into a bundle and disappears making room for more steam.

Bactericidal Action—Resistant dry spores are destroyed in thirteen minutes by saturated steam at 250° F (Fig. 94)—an exposure which is practicable and does not destroy textile fibers. A final advantage is that textiles feel dry when removed from the sterilizer.

Limitations—Despite the outstanding advantages which seem to make saturated steam the ideal microbicide there are limitations which decrease or nullify its effectiveness. These have been described but few surgeons realize their importance.

When steam is *superheated* its bactericidal power is diminished and if superheated enough it chars textiles. One common cause of superheating is the maintenance of a higher pressure and hence temperature in the sterilizer jacket than in the chamber. The hotter jacket adds heat to the saturated steam in the chamber driving it away from the vapor liquid boundary. Extreme superheating occurs when fabrics are put into the sterilizer while steam pressure is maintained in the jacket. The textile fibers are heated to the temperature of the jacket and are also dehydrated. When steam is turned into the chamber the thirsty fibers absorb water from the steam liberating latent energy which is dissipated by superheating the preheated fabric. The temperature of the fabric reaches the charring point and *potent combustion* may occur when such fabrics are removed from the sterilizer.

Lesser degrees of superheating are caused by putting *anhydrous fabric* into the sterilizer. Such fibers may adsorb as much as 7 per cent of their dry weight of water from the steam and liberate excess latent energy which superheats the textiles. The cumulative effect of superheating can be readily demonstrated. Identical samples of textile were sterilized simultaneously during the winter months when the humidity in heated rooms is low. The samples which were laundered (hydrated) immediately prior to sterilization lost 50 per cent of their tensile strength after seventy trips through the laundry and sterilizer whereas the samples which were sterilized repeatedly lost 73 per cent of their tensile strength.¹⁹

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exposed for interchange of air and steam and retard sterilization.⁸⁻¹⁰ Second crowding packages of textiles together results in compression of their contents and penetration by steam is made difficult. Sterilizers should be equipped with shelves so that maximum utilization of space is possible without piling packages on top of each other. The widely used basket shaped carriages should be abandoned because it is impossible to load such a basket without compressing the packages at the bottom. Third sterilizers must be loaded to provide a horizontal path for the escape of air from all non-porous containers in the load. Other wise every hollow where water might pool will trap air.

Factor in Effect of Steam Sterilization

The routine control of steam sterilization of surgical dressings requires knowledge of four factors which influence the efficacy of the process.

1. *The quality of the steam being used in the sterilizer must be determined.* The temperature of the fluid in the chamber exhaust line indicates whether air, steam or a mixture of the two occupy the lower portion of the sterilizer. If the chamber pressure is 15 psi the temperature in the properly designed exhaust line will rise to 50° F when saturated steam has displaced the air and fills the chamber.

2. *The period required for the steam to penetrate the largest bundle must be known.* This can be predetermined by establishing a standard size, shape and internal arrangement for the largest bundle. A laparotomy kit weighing 18 pounds can be wrapped in a package 24 by 15 by 8 inches in such a fashion that saturated steam will be in contact with its entire contents within fourteen minutes after the temperature in the exhaust line rises to 250° F.

The general principles of packaging the supplies for a laparotomy are illustrated. The wooden trough (Fig. 95) limits the size and shape of the package to standard dimensions which permit uniform penetration. The tapper con-

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sists of two sheets (63 by 90 inches) folded crosswise to form four thicknesses 63 inches long and 45 inches wide the sheets are then draped in the trough as the first step in making the package. Supplies needed during the operation (sponges abdominal pads additional towels final dressing) are placed in the bottom layer. The laparotomy sheet suitably folded and rolled to afford easy draping as well as to provide channels for ready penetration to the center of the bundle occupies the center of the second layer. This sheet designed to cover the whole field from anesthetist's screen to patient's feet is pleated from top and bottom toward the opening for the operative field. The pleated sheet is then rolled from either side toward the center to form relatively open parallel rolls. When properly located in the package the rolled sheet effectively divides the contents into four small sections which are easily sterilized. Towels for draping the skin are piled on top of the rolls gowns for the team are arranged about this central pile to fill the space in the wooden trough.

The two uppermost layers of the wrapper are brought across the top of the bundle and tucked into the crevice between the pile of supplies and the sheet lining the trough. The folded edge of the wrapper laps over these thicknesses and the other layers are then overlapped to close the package against accidental contamination. The bundle is completed just as any paper wrapped package and secured by a library tie of Venetian blind cord. This package can be opened by an unsterile nurse without danger of contamination. Its contents are instantly accessible in the order in which they are required during operation.

3 *The sterilizer must be loaded to provide a horizontal path for the escape of air.* The laparotomy bundle is arranged internally so that air is displaced most readily when the package is placed in the sterilizer on its 7 by 8 1/2 inch side. A free space must be provided for the circulation of steam above and below each package. Crowding of packages and compression of their contents must be avoided.

4 *The period of continuous exposure to saturated steam must be measured.* Continuous exposure is essential because as steam penetrates a package it condenses on the fibers of the fabric

in quantities proportional to the heat required to raise the material to the temperature of the steam. The heating spread centripetally in a distinct zone of demarcation the temperature necessary for sterilization exists only where the goods are moist a few centimeters in advance of the zone the fabric is dry and relatively cool. If this orderly heating is stopped the outer wet shell of fabric cools and must be reheated. If the outer third of the package cools to 212°F 30 per cent more

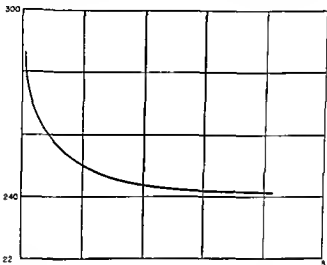


Fig. 94—A graph showing the relationship between time and temperature. The y-axis represents temperature in degrees Fahrenheit (F), with markings at 22, 240, and 300. The x-axis represents time in minutes (min), with markings at 9. The curve starts at approximately 280°F at time 0 and decreases, leveling off at 240°F after about 6 minutes.

steam is required to reheat the outer wet shell (the outer third of the package by weight) because the moisture left in the fabric by the initial heating requires heat in addition to that needed by the textile.

The operation of a steam sterilizer is based upon the proper correlation of these four factors with the thermal death time for bacteria illustrated in Fig. 94. The sterilizing period for a properly loaded sterilizer is timed from the moment that

saturated steam fills the chamber as indicated by the temperature of the fluid in the chamber exhaust line. Sufficient time must be allowed for penetration of the largest bundle and destruction of bacterial life.



Fig 95—G l p p l f p k g g f r m p t b v
m S t vt

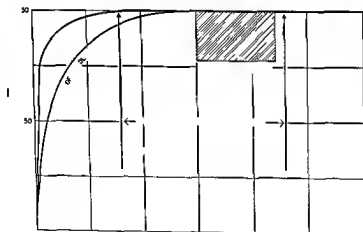


Fig 96—T m t m p r a t u r e l t a m s h i p d g t m f s t a d a r d
b d l a l l s t r a d m F g 95

For example in a large sterilizer the temperature in the exhaust line indicated the presence of saturated steam (250° F 15 psi) in seventeen minutes (Fig 96). The temperature in

the center of a standard bundle did not indicate complete penetration by steam until fourteen minutes later. Thirteen additional minutes are necessary for microbicidal action. Therefore a period of thirty consecutive minutes provides for complete penetration of the load plus ample exposure of the least accessible spore in the bundle to saturated steam at 250° F. with a margin of three minutes.

After the textiles have been sterilized the steam is vented and the load dried by letting the sterilizer door stand ajar for fifteen minutes while the steam pressure is maintained in the jacket. A partial vacuum may be developed in the chamber to aid drying if desired but is unnecessary.

STERILIZATION OF RUBBER GOODS, UTENSILS AND SUTURES

Rbb Gcd

Rubber *gloves* are difficult to sterilize because air is readily trapped inside the fingers and palm of the glove unless a definite channel is provided for the prompt interchange of air and steam. This is accomplished by inserting a folded sponge in the cuff of each glove. A gram of powder can be dispersed throughout the meshes of one sponge which can be used as a powder puff. Talc is so impenetrable by steam that its sterilization is not practicable unless the individual grains are exposed to steam in this manner. Gloves must be wrapped so that the position of the thumbs is known and the packages must be placed in the sterilizer so that the gloves stand on edge with the thumbs up to insure clearance of air. Where the wet glove technique is used the gloves are sterilized in a special muslin folder which has a tab that can be inserted in the cuff. The gloves can be easily shaken from the folder into the basin of germicide.

Rubber *tubing*, asepto-syringe bulbs and the like may also trap air. Proper positioning will provide a horizontal path for the escape of air but this is often inconvenient. It is easier to rinse the lumen of the rubber article with water immediately prior to sterilization. The moisture remaining on the inner walls provides for sterilization when heated to 250° F. and causes the displacement of the air as described in the section

on the sterilization of solution Rubber goods should be sterilized for thirty minutes at 250° F. Gloves are spoiled by puncture rather than by sterilization 30 per cent are punctured the first time they are used

The chemical disinfection of bulky rubber goods (anesthetists masks Kelly pads etc.) is considered later

Utensils

Basins and other utensils are advantageously sterilized by saturated steam because they can be wrapped for easy handling and storage Because the kits are dry when removed from the sterilizer odd items of dry goods customarily used in the basins may be sterilized in them Thus abdominal packs can conveniently be sterilized in the saline basins It is imperative to wrap utensils so that they can be placed *on their sides* in the sterilizer to insure a horizontal path for the escape of air If several basins are nested together care must be taken that the position of the inner ones is similar to that of the outer ones Properly wrapped and loaded kits of utensils can be sterilized with bundles of textiles by exposure to saturated steam at 250° F. for thirty minutes

Terminal Sterilization of Utensils—The basins from cases where dangerous organisms have been encountered are emptied into the lickpail and then nested in a muslin bag for sterilization in saturated steam at 250° F. for thirty minutes Sufficient chlorinated lime is added to the fluid in the lickpail to make a solution of 1:1000 free chlorine which disinfects the pail

Silk Catgut and Nylon Sutures

These materials must be sterilized by steam because absolute sterility is essential for their successful use Silk and nylon sutures are stronger after steam sterilization than after boiling because they are dry and thus have their maximum tensile strength when the surgeon uses them All can be sterilized repeatedly without appreciable deterioration provided superheating is avoided by moistening the sutures slightly immediately prior to sterilization when the relative humidity is low and by avoiding faulty operation of the sterilizer

The handling properties of silk can be improved by dipping the hanks in molten beeswax. The hank can then be folded tucked into a test tube wrapped and sterilized by thirty minutes exposure to saturated steam at 250° F. Sterilization is possible because beeswax adsorbs 10 per cent of its weight in water during sterilization.

STERILIZATION OF SOLUTIONS

The sterilization of solutions presents an apparent inconsistency in technic because flasks are put in the sterilizer in an upright position and no provision is made for a horizontal path for the escape of the air from partially filled flasks. The presence of water alters the problem however. The temperature developed in a load of textiles depends upon the temperature and hence the pressure of the saturated steam that condenses inside the bundle. The temperature of the water in a partially filled flask depends only upon the temperature of the walls of the flask. In saturated steam therefore the temperature of the liquid ultimately approaches that of the surrounding steam and vaporization inside the flask becomes sufficiently rapid to fill the flask with saturated steam driving off the air even though there is no horizontal path for its escape. The air is displaced so completely from unstoppered flasks that when the flask is stoppered and cooled a 9 inch vacuum results.

The sterilization of solutions presents a second problem not encountered in sterilizing dry goods. At the end of the sterilizing cycle flasks of solutions are as hot as the surrounding steam and because the liquid is subjected to the vapor pressure of the steam it is in a stable condition. However if the steam pressure in the sterilizer is vented this equilibrium is upset the solution becomes too hot for the pressure exerted upon it and excessive vaporization occurs. This may result in concentration of the solution or if the vaporization is explosive much of the solution may be lost during the violent ebullition of steam which occurs when the pressure is relieved. To prevent this the steam to the sterilizer jacket as well as to the chamber should be shut off and the whole sterilizer permitted to cool to 200° before the sterilizer door is opened.

Under these circumstances the solutions lose heat to the steam in the sterilizer which in turn loses heat to the walls of the sterilizer. The pressure decreases as the temperature falls and equilibrium is maintained through the cooling cycle.

Successful sterilization of solutions also demands *a detailed knowledge of their characteristics*. It is useless to attempt to sterilize a chemical that decomposes at a temperature lower than that used in the sterilizer. Hydrogen ion concentration is important since many chemicals are stable only under specific conditions. It is therefore important to use pure distilled water as the diluent. Improperly rinsed glassware may add residual alkali from detergents to the solution and cause decomposition. The use of soft glass may permit the development of an alkaline reaction at the liquid glass interface.

For example dextrose solution can be sterilized without deterioration when the pH is acid and the containers are made of hard glass. If the pH is alkaline caramelization occurs and the solution turns brown. Solutions of procaine hydrochloride can be sterilized in a steam sterilizer in hard glass containers if 0.001 normal hydrochloric acid is used as the diluent. On the other hand solutions of sodium tetraiodophenolphthalein must be kept alkaline or precipitation occurs. This drug must be dissolved without shaking in carbon dioxide free water, sterilized and hermetically sealed so that carbon dioxide has no access to it. The three solutions mentioned can be sterilized at 250° F. for thirty minutes, hermetically sealed and stored indefinitely without appreciable deterioration.

REQUISITES FOR EFFECTIVE STERILIZATION BY STEAM

Reliable routine steam sterilization can be carried out only when

1. Permanent personnel are charged with the responsibility for proper packaging and loading of supplies and operation of the sterilizer. This group must be well trained and perform their duties wholeheartedly.

2. Sterilizers are provided with an adequate quantity of steam (pounds of steam per hour rather than pressure head) to permit prompt heating of the load.

3 There is a means of measuring (by thermometer or otherwise) the temperature of the fluid in the exhaust line of the sterilizer

4 A timer automatically indicates the maintenance of a temperature of 50° F in the exhaust line for thirty minutes

5 There is adequate sterilizer capacity (cubic feet of usable space not number of sterilizers) to permit operation at no more than 85 per cent capacity during the normal working hours of the sterilizer attendants. Such capacity is essential to eliminate the necessity for overloading sterilizers. It is folly to expect sterilization of a volume of supplies requiring thirty to thirty six hours for proper sterilization in a twenty four hour period

6 Sterilizers are maintained by periodic inspection by a trained mechanic who understands the design and use of sterilizers and who appreciates the importance of their proper maintenance

The periodic testing of sterilizer by the planting of cultures is a complex technique which is too likely to lead to erroneous conclusions to be advocated as a general method. If used the technique outlined by Ecker² should be followed. The use of tell tale indicators in the packs is not justified because they perform erratically and are difficult to interpret

TERMINAL STERILIZATION OF DRY GOODS

Unsoiled dressings from operations in which pus or dangerous spores have been encountered are gathered into the muslin bag provided for the sterilization of utensils. They are sterilized along with other dry goods in saturated steam at 50° F for thirty minutes

All linen and garments from such cases are gathered into a clean duck laundry bag marked *communicable* and sent to the laundry. Wet linen must be wrapped in sufficient dry material so that there is no danger of bacteria laden moisture setting through

In the laundry the bag is emptied into a breaker and the bag is thrown in also. Cold water is added and the breaker run for twenty minutes to wet and dislodge dried blood, feces, pus and bits of tissue. Soap is then added until a stiff lather

forms and the breaking continued while the water is heated to boiling. This is usually done by injecting steam into the water. Sufficient soap is put in to form a second lather and a 5 per cent excess of soap is added to insure alkalinity enough to destroy spores. After fifteen minutes exposure to boiling water the load is treated as ordinary laundry. If suitable laundry equipment is not available soiled contaminated dry goods may be immersed in a 1:1000 solution of chlorine made by diluting chlorinated lime with an appropriate quantity of tap water. Colored fabrics may be bleached by this process.

STERILIZATION OF INSTRUMENTS

The sterilization of instruments presents several problems which must be considered in order to provide utmost safety for the patient, long life for the instrument and convenience for the surgeon. Surgical instruments are of three kinds: (1) those which withstand sterilization by moist heat; (2) those with cutting edges which corrode readily when exposed to moist heat; and finally (3) those which are delicate or made of materials which are not heat resistant and which must be sterilized by chemical means.

Circumstances also determine the method of sterilization. For *proper* sterilization a technic should be chosen which destroys all spores and as will be seen this predicates the use of all alkali in the nonpressure sterilizer or exposure to steam at temperatures higher than 50° F. For the *emergency* sterilization of instruments a method must be chosen which is so rapid that the surgeon is not inconvenienced by a prolonged period of sterilization. Finally, there is the *terminal* disinfection of instruments known to be contaminated with dangerous organisms from an abscess, a gangrenous region or the gastro intestinal tract. To be reliable a technic for the sterilization of instruments must be sufficiently rapid to eliminate the human tendency to circumvent a lengthy procedure. Inconvenience, face saving and impatience militate against any technic which requires more than ten minutes for completion. Even that period is too long to be practicable for emergency sterilization. The technic must also be selected on the basis of how the instruments are cared for between operations.

Instruments which are lubricated prior to storage cannot be sterilized unless precautions are taken to remove the oil or grease. The same is true of spots of blood, pus, or feces which may accumulate in the serrations of the jaws, in the locks, or in the catches of instruments. The incrustations protect bacteria and delay sterilization beyond the period required for a mechanically clean instrument. All instruments should be unlocked when moist heat is used because tightly opposed metal surfaces are not wetted. These general principles are violated frequently.

P o p u l a r S t e r i l i z a t i o n

The *nonpressure* sterilization of instruments depends upon the use of *boiling water* as a microbicide. The limitations of this technic are well recognized. The maximum temperature attainable is 212° F. at sea level. That temperature is not lethal to spores. Therefore instruments prepared by boiling may still be contaminated with spore-bearing organisms. Nonpressure sterilizers which are equipped with devices to control the amount of steam thrown off when the water boils must be carefully supervised because such devices may depress the temperature too much. To be reliable in the average nurse's hands, such sterilizers should be equipped with a thermometer so that faulty operation of the vapor control is evident. A final limitation is the fact that air is readily trapped under inverted objects and organisms are likely to escape destruction unless the boiling period is prolonged.

The microbicidal efficiency of nonpressure sterilizers can be increased by filling and covering everything with water so that air pockets are eliminated. The addition of 2 per cent sodium carbonate (sal soda) or 0.1 per cent sodium hydroxide (lye) to alkalize the water not only decreases the corrosive action of boiling water but also increases its bactericidal effect. The reliability is also increased by keeping oil and grease out of the sterilizer and by unlocking all instruments so that the boiling water can contact all surfaces. Instruments should be boiled for thirty minutes. In boiling 2 per cent sodium carbonate or 0.1 per cent sodium hydroxide solutions instruments are sterilized by fifteen minutes exposure. The

latter conditions are sufficient to destroy all but the most resistant dry thermophilic spores and organisms protected by incrustations of protein or a coating of grease

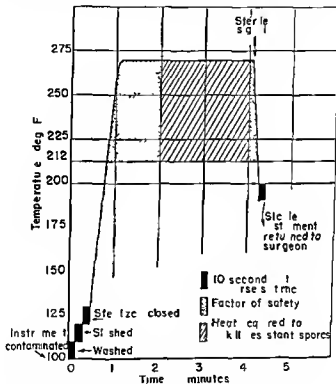
The use of *pressure sterilizers* for the sterilization of instruments is becoming more common. The problems presented by pressure sterilization are similar to those of steam sterilization of dressings except that instruments present surfaces to be sterilized rather than bulky masses of textile fibers. Hence penetration is not a problem. Air clearance is important chiefly because the air prevents mechanical contact between the steam and the instruments and lowers the ultimate temperature attained. Steam sterilizers have a deleterious effect on instruments because steam condenses on them and corrosion occurs under the droplets of condensate. Condensation can be reduced to a minimum by preheating the instruments to sterilizing temperature by heat radiated from the steam jacketed chamber wall before the steam is turned into the chamber to do the actual sterilizing. Instruments which are to be stored should be dried after sterilization by leaving them in the chamber with the sterilizer door ajar while steam pressure is maintained in the jacket.

There are two distinct techniques in use for the sterilization of instruments by steam under pressure. One is based upon the use of steam at 250° F for fifteen minutes, the other upon steam at 270° F for three minutes (Fig. 94). With either technic the instruments must be unlocked, clean and free from oil or grease, and the exposure must be based upon the temperature developed in the exhaust line of the sterilizer. A reliable technic for the sterilization of instruments (dirty as well as clean) is described under Terminal Sterilization of Instruments.

Emergency Sterilization

The need for emergency sterilization arises daily. Every surgeon has experienced the exasperating delay caused by the omission of instruments from the kit, the inadvertent dropping of an instrument to the floor, or the unanticipated need for instruments required by a change in the operative procedure. In many clinics, quick sterilization, boiling for one or two

minutes in a small electric sterilizer or chemical disinfection (just wipe the instrument with a germicide) are sanctioned because of the emergency. In operating rooms where more thorough methods are used the impatient surgeon often stampedes a timid circulating nurse into returning an instru-



F 97-T emp ture l nsh p h gh h y l f st nli
l gn d primarily f h nli z f an trum g d d d

ment to the operative field before it has been adequately sterilized.

Safe emergency sterilization can be carried out quickly and efficiently in a special *steam sterilizer*. Steam is admitted to the jacket of this sterilizer prior to operation and a pressure

of 27 psi is maintained during the procedure so that the sterilizer is instantly available and condensation on the chamber walls is prevented. Instruments must be scrubbed with soap and water and slushed in a fat solvent. The clean unlocked instruments are placed in the sterilizer in a perforated metal tray and the door closed rightly. Steam is then admitted to the chamber so rapidly that a sterilizing temperature of 270° F is attained in forty seconds (Fig. 97). Spores of the most heat resistant organisms are destroyed at 270° F in two minutes (Fig. 94). After a three minute sterilizing period pressure in the chamber can be relieved quickly. A detachable handle is then fitted to the sterilizing tray and the sterile instruments are carried to the operative field. This technique enables the circulating nurse to return an instrument to the operating table in less than five minutes with no compromise of aseptic technique. Because of the rapid action and high temperature attained in this sterilizer spotting and corrosion of instruments are eliminated.

The emergency sterilizer described has a profound effect upon instrument technique. The fact that instruments are available quickly permits the routine use of smaller instrument kits because should the need for more instruments arise they can be supplied without delay. Duplicates of special often expensive instruments are unnecessary, savings in labor and maintenance of instruments are possible and the instrument inventory can be decreased in quantity and increased in quality.

T m | St | t f l t m t

The need for terminal disinfection of instruments from septic cases has been recognized and special techniques for the routine sterilization of such instruments have been devised. The only bacteriologically safe techniques are based upon the exposure of such instruments to moist heat above 250° F. Soaking contaminated instruments in germicide, prolonged boiling after thorough scouring and scrubbing or combining these in various ways is not only time consuming but also re-

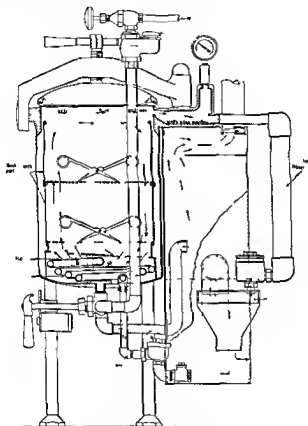
Eth	vt l m y b	sed A	mm	l l	su h
S d S l	ll b f	d les	vp	d h h d	g f b g
vp l					

moves the instruments from circulation. What is of greater importance to safety, dangerous spores may be spread throughout the operating room during the cleaning process. If nonpressure sterilizers may be contaminated with spore which survive hours of boiling.

Instruments contaminated with pus, blood, tissue, or feces can be sterilized by immersing them in a 10 per cent soap solution and autoclaving them at 50° F for thirty minutes. This practice has the disadvantage of using equipment primarily designed for another purpose. The interior of the autoclave is usually fouled with soap and denatured proteins which are spattered on the chamber wall when the steam is vented. The danger of scalding the attendant who removes the instruments from the sterilizer is great.

A safe, rapid technique for cleansing and sterilizing contaminated instruments is to expose them to a detergent solution in a sterilizer designed to remove the oil and scum from the surface of the water, leaving at the most a monomolecular film of oil which can be sterilized.¹ This is conveniently done in a vertical autoclave constructed to withstand an operating pressure of 77 psi. The soiled instruments are collected in a stainless steel bucket directly from the instrument table by the scrub nurse. The bucket is placed in the sterilizer over a baffle which forces the water to circulate through perforations in the bottom of the bucket (Fig. 98). A steam coil located beneath the baffle supplies adequate heat for rapid sterilization and sets up convection currents in the water to carry the oil and grease which leave the instruments and rise to the surface toward an overflow at the rear of the sterilizer. The continual rise in the water level due to the expansion of the heating water carries the oils and scum formed by the blood and pus over a knife edge overflow into a reservoir whence it is discharged into the drain. The addition of a detergent to peptonize the proteins and saponify and peptize the greases removes all dirt and eliminates the necessity for mechanical cleansing. The temperature of the water is raised to 273° F in seven minutes and the steam supply is shut off. The water is rapidly drained into a flash tank, exposing the instruments to saturated steam for approximately one minute while the pres-

sure is being relieved. The residual heat in the instruments is sufficient to flash any adherent moisture and the clean dry sterile instruments are ready for immediate use upon removal from the sterilizer.



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An insulated oven with shelves made of electrically heated plates is an ideal method for sterilizing sharp instruments because they are heated by actual contact with a plate maintained at 320° F (Fig 99). The heating is rapid and uniform. Minimum exposure is one hour. Temperature control is easy and the instruments are clean and ready for immediate use upon removal from the sterilizer.

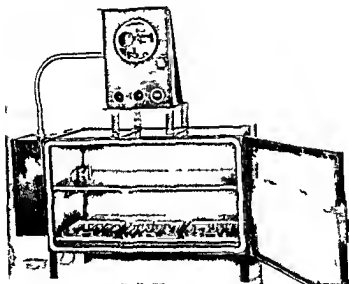


Fig 99—Dry heat sterilizer. The instrument is placed on the heated plate and the temperature is maintained at 320° F.

If the above facilities are not available, cutting edge instruments can be sterilized by *boiling* for fifteen minutes in a solution containing 2 per cent sodium carbonate. Corrosion is greatly inhibited by the carbonate and the cutting edges are but slightly dulled by single exposures to boiling water. The cumulative effect of boiling is marked, however, and repeated boiling of scissors, for instance, soon causes noticeable dulling.

The *emergency* sterilization of cutting edge instruments can be carried out satisfactorily in the emergency sterilizer previ-

cause the usual deposits of protein are readily removed or sterilized.

This sterilizer also effects economies in time and instruments in the operating room. The fact that grossly contaminated instruments can be made safe for immediate use in terms of being out of circulation for hours or days makes it possible to use a lot of instruments repeatedly. An operating room provided with an emergency sterilizer and an instrument washer has the ideal facilities for the care of the bulk of surgical instruments.

STERILIZATION BY DRY HEAT

CUTTING IDLE INSTRUMENTS—Cutting edge instruments present problems in sterilization since moist heat and moisture chemically dull the cutting edges because electrolytic action is concentrated on the sharp edge and excessive corrosion occurs rapidly. Dry heat has proven the most satisfactory means of sterilization. It must be used with care because temperatures but slightly above the necessary for sterilization draw the temper of the cutting edge and ruin the instrument. Of the many methods for dry heat sterilization three merit discussion.

The *oil of spili* is an effective but dangerous way of using dry heat. The instruments are simply immersed in an oil bath at 370° F. for one hour. Accurate temperature control is difficult. The personnel are likely to be burned and the hot oil is a fire hazard. Fumes from hot oil are obnoxious to many and the whole process is messy.

Hot air ovens are widely used. Many are satisfactory although the oven heaters have a wide temperature differential in various parts of the sterilizer. The period of exposure must be based upon the actual temperature of the article to be sterilized rather than upon the temperature of the air in the sterilizer. For example, it takes one and one half to two hours for a saline in a 2 ounce glass container just to reach the temperature of the oven. It is incumbent upon the user to determine the heating period of every class of article sterilized and to perme the sterilizer temperature through heating of the load before running the exposure. Determination of the heating for individual sterilizer article combinations becomes a job to do very widely.

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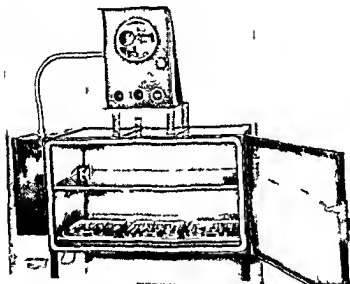


Fig 99—Dry heat sterilizer. The temperature is maintained at 320° F.

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The *emergency* sterilization of cutting edge instruments can be carried out satisfactorily in the emergency sterilizer previ-

ously mentioned without appreciable dulling due to single exposures to saturated steam at 270° F for a three minute period

CHEMICAL DISINFECTION

The most controversial aspect of aseptic technique has been the chemical destruction of bacterial life. Recently tests have been devised and standards established so that the evaluation of chemicals as germicides is practical and significant. The Department of Agriculture has forbidden the use of the words "sterile" or "sterilize" in conjunction with germicides because the majority are bacteriostatic rather than bactericidal in the concentrations applicable in surgery. Most germicides are selective, killing some organisms readily and not destroying others. Many are erratic and kill only when used in specific concentration as is the case with alcohol. None are reliable unless used carefully. Proteins, blood, pus, and greases prevent their action. With all prolonged exposure (hours and days) is essential for destruction of dry spores. In surgery, chemical disinfection is therefore used only when heat would destroy the articles to be sterilized.

FORMALDEHYDE—Formaldehyde is one of the few germicides suitable for the disinfection of instruments. Since its synthesis in 1867 it has been a popular means of disinfecting inanimate objects. The demonstration that dry formaldehyde gas is ineffectual has led to the abandonment of fumigation except in surgery where it is still used by many.

Aqueous and alcoholic solutions of formaldehyde are reliable germicides for surgical instruments provided certain well recognized precautions are taken. The articles must be mechanically clean and free from grease, blood, pus, or feces which prevent contact between the germicide and the organisms they contain or cover. Prolonged exposure—eighteen hours—is necessary to destroy spores. The drug irritates and dries the skin and causes contact dermatitis in some individuals. Since it irritates mucous membranes and wounds all residual formaldehyde solution must be allowed to evaporate or be rinsed from instruments. The following formulae may be used for the sterilization of instruments, ampules and so forth.

() S d t b t	50	gm
F m l (10 ^{cc})	1 d 1000	
(b) F l (38 ^{cc})	130	gm
P t n t	0 15	gm
S d m h y d u d	0 012	gm
L h y l l l l C.P (9 ^{cc})	q d 1000	
() F m l (38 ^{cc})	135	
S d m h y d u d	10	g
D l l d	1 d 1000	

A stabilized corrosion inhibitive solution such as Bard Parlcr's germicide justifies its cost where instruments are stored in germicide.

Disinfection with *formaldehyde gas* is possible only in a specially designed sterilizer which permits the evacuation of air (40 mg Hg) so that formaldehyde will penetrate packages or fill the lumen of tubes. A relative humidity of 80 per cent is necessary to activate the gas. Under these conditions 8 mg of formaldehyde per cubic foot is lethal at 70° C in thirty minutes. The method is suitable for the disinfection of optical instruments and electric cords.

Bulky rubber goods are disinfected by immersion in an alkaline solution of formaldehyde for two hours.

F m l (38 ^{cc})	135
S d m h y d u d	10 gm
D l l d t	q d 1000

Thorough cleansing and soaking in a solution of chlorinated lime containing 1/1000 free chlorine is also reliable and avoids the use of formaldehyde.

ZEPHIRAN—Delicate ophthalmologic instruments, cystoscopes and the like where residual formaldehyde must be avoided can be disinfected by boiling for eighteen hours in the following solution:

Zeph (10 ^{cc})	1
l	5 g
D l l l	1 d 1000

This germicide is nonirritating, has a low toxicity, and is effective against spores.

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MINIMIZING THE CONTAMINATION OF OPERATIVE WOUNDS †

DERYL HART MD FACS†

THE subject of limiting the contamination of operative wounds will be discussed under the following nine headings which consider either the routes by which such contamination occurs or means of reducing and controlling it after it occurs

- 1 Limiting contact contamination
- 2 Limiting contamination from the skin of the patient and personnel
- 3 Limiting contamination by way of the lymphatic stream
- 4 Limiting contamination by way of the blood stream
- 5 Limiting contamination by way of the air
- 6 Limiting contamination when operating in the presence of contaminated material or for pre-existing infection
- 7 Reducing wound contamination before closure
- 8 Limiting the multiplication of contaminants within the wound
- 9 Limiting the contamination of the wound from the external surface during the postoperative period

F m th D p run f S g ry D k U ty S h l f M d
d D k H p l D h m N C
† N mp ll b m d t g d t th m h rs wh h
b d h l tu wh h h d l p d h b
l ct mp rt w firs ll d t h at tu f th g l
w ld by L t Th p p ss d ho f th th d
l p d l g ly f m th l g f h p p rs d f m h m y
p hl l l h pp d
H b f h p l f expl d f tu h
w p n h p h ascp tu l h b h k d pe dly
d g l p y rs A l rt k es m p
g rally p d h b b ght h rt d h h e
b g rally g d h h pons b l ty f th h
g esp d gly g mph
† Profess r f S g ry D k Um rs ty Sch l f M d Ch f f
S ff D k H p l

1 LIMITING CONTACT CONTAMINATION

Before the days of antiseptic surgery contact contamination undoubtedly played the dominant role in the infection of clean operative wounds. Its significance was early recognized and it has received the greatest attention throughout the development of both antiseptic and aseptic technique. Since its importance is so thoroughly understood and methods of control so widely practiced the consideration given to it here will be abbreviated.

The subject of sterilization of all supplies and instruments which reach the operative field has been covered by Dr. Carl Walter. We may thus omit from this discussion what originally constituted the major problem in the elimination of contact contamination.

In order to avoid insofar as possible the subsequent contamination of these supplies and the open wound not only should every individual in the operating room be contact conscious and act as a guard against the oversights of others but every focus for bacterial spread should be eliminated if possible. The use of *forceps* sterile except for the handles for the utility nurse to handle sterile supplies is widespread and when not in use the sterile portion of these are usually kept submerged in a disinfectant solution. We may be negligent in not insisting that the *hands* of the utility nurses be as free as possible of highly pathogenic bacteria. The hand may be contaminated by blowing the nose, suppressing coughs and sneezes, touching contaminated dressings and so on. I once heard the criticism that "You wash your hand and you think you are clean; if you did not wash them you would know that you are dirty" and would thus avoid any possibility of spreading contamination by the hands. This advice can be improved by having everyone keep their hand as free as possible of gross contamination by washing and still keep themselves aware of their unsterile condition by cultures at suitable times.

The *uniforms* of the doctors, nurses, orderlies and other personnel in the operating room come from the laundry, practically free of bacteria. They should be fresh daily and should not be worn after being subjected to contamination in con-

tact with infected cases from wear on the wards from long wear in the operating rooms or from talking sneezing or coughing. The usual *mask* if worn loosely may direct the bacteria from the nose and mouth down on the uniform. We have found by culture that the longer the uniform is worn the heavier the upper front becomes contaminated with the nose and throat flora of the wearer.

It seems hardly necessary to issue the warning that *coughing* and *sneezing* in the operating room should not be tolerated and that *talking* should be kept to the minimum. Furthermore it should be recognized that every individual with a *respiratory infection* increases the danger of contaminating the sterile supplies and open wound either by contact contamination or more likely by building up the contamination in the air as discussed under 5.

The *personnel* on the operating room floor should be limited to the minimal number for efficient work and visitors should not be allowed particularly when they are not contact conscious. The *visitors section* should have an entrance not on the operating room floor and for the purpose of limiting the air contamination as discussed under (5) should be separated from the operating room by a glass partition.

Operations on *infected wounds* should be performed in rooms set apart for this purpose and when this is not possible should be postponed until all clean operations for the day have been completed. Under any condition every effort should be made to limit the spread of pus and after the operation has been completed the entire room should be considered as contaminated and treated accordingly. All linens should be sterilized preferably in a separate sterilizing room used for this purpose. Instruments and gloves should be sterilized immediately without being allowed to come in contact with any other equipment. The equipment and floors should be washed with an antiseptic solution and all members of the personnel should scrub their hands and arms thoroughly before beginning another operation.

Carelessness should be reduced by making it the responsibility of every individual to guard against any break in technique by anyone on the team. A guard is all the more important

when a nonsurgical visitor or a new intern nurse or orderlies comes on the floor. Familiarity breeds contempt and it is very easy for one individual to touch another on the back, touch his back against some part of the sterile field, draw the inner opening of the sterile gown across his chest before the prepared hand is passed through this opening or to allow the sleeves of his gown to touch unsterilized areas when they are being put on to mention only a few breaks that not infrequently occur.

2. LIMITING CONTAMINATION FROM THE SKIN OF THE PATIENT AND PERSONNEL

This is really a part of the control of contact contamination but the problem of disinfecting the living skin is so different from the sterilizing of supplies and its limitations are so great that it is best given separate consideration.

The number of bacteria on the surface of the skin can be reduced greatly by scrubbing with soap and water but this reduction by surface cleansing cannot be carried below a certain level. However repeated daily scrubbing combined with proper care of the skin and avoidance of unnecessary contamination will result in a lower surface bacterial count. After scrubbing treatment of the skin with appropriate chemicals will cause temporarily a very low surface bacterial count, but none of these agents will penetrate to the bacteria located in the sebaceous glands and hair follicles in the deeper parts of the skin. Recent unpublished studies by Dr. Durward Lowell of the Duke Surgical Staff have failed to show any bacteria in the sweat glands while on the skin surface the sweat and acid tends to inhibit the bacterial growth. He also found that with a nonbactericidal alkaline agent in the gloves, the bacterial count on the surface of the hands at the end of an hour was far greater than the count before scrubbing. However these normal inhabitants of the skin are of relatively low virulence and the importance of avoiding when possible and of always removing or killing as many as possible of the more highly pathogenic temporary surface contaminants cannot be too strongly emphasized.

PERSONNEL—Spread of contamination from the skin of the hands and arms of the personnel can be controlled by *sterile gowns* and *rubber gloves* so long as the former remain dry and the latter are not punctured. Any member of the personnel suspected of being a *carrier* of highly pathogenic bacteria on the skin because of recurring furuncles, boils, or carbuncles, and having this proved by cultures, should be relieved of operating room duties until the condition has been corrected. Likewise the patient under similar conditions should not have a clean operation of election until it can be shown that he does not harbor these highly pathogenic bacteria in his skin. While theoretically the contamination from the hands of the surgeon can be controlled by the use of gloves, the frequency with which the modern thin gloves are punctured makes a wide breach in our operative technic, particularly during hot weather when the glove may contain large amounts of contaminated perspiration. Every precaution should be taken to avoid perforation, and if this occurs the glove should be changed immediately. Possibly some day we will have a thin glove that is less easily punctured or we may have to return to the heavier gloves of former years.

PATIENTS—Control of contamination from the skin of the patient is a more difficult problem. The bacterial growth in the deeper parts of the skin is in the sebaceous glands and hair follicles and is greatest where these structures are most numerous. Likewise the degree of surface contamination and the rapidity of its recurrence after preparation for operation varies for different parts of the body, being greater where there are larger numbers of these structures. As an example, we have found the degree of skin surface contamination to be far greater at the end of the repair of inguinal hernias than at the end of thyroidectomies in women.

Since the skin incision must pass through these deeply situated glands and hair follicles and since the skin sutures may penetrate them, a certain amount of wound contamination from this source is inevitable. This can be minimized by discarding the scalpel used to make the skin incision and by immediately isolating the surface and cut edge of the skin from the remainder of the wound and not exposing it again.

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2. LIMITING CONTAMINATION FROM THE SKIN OF THE PATIENT AND PERSONNEL

This is really a part of the control of contact contamination but the problem of disinfecting the living skin is so different from the sterilizing of supplies and its limitations are so great that it is best given separate consideration.

The number of bacteria on the surface of the skin can be reduced greatly by scrubbing with soap and water but this reduction by surface cleansing cannot be carried below a certain level. However, repeated daily scrubblings combined with proper care of the skin and avoidance of unnecessary contamination will result in a lower surface bacterial count. After scrubbing treatment of the skin with appropriate chemicals will cause temporarily a very low surface bacterial count but none of these agents will penetrate to the bacteria located in the sebaceous glands and hair follicles in the deeper parts of the skin. Recent unpublished studies by Dr. Durward Lovell of the Duke Surgical Staff have failed to show any bacteria in the sweat glands while on the skin surface the sweat being acid tends to inhibit the bacterial growth. He also found that with a nonbactericidal alkaline agent in the gloves the bacterial count on the surface of the hands at the end of an hour was far greater than the count before scrubbing. However, these normal inhabitants of the skin are of relatively low virulence and the importance of avoiding when possible and of always removing or killing as many as possible of the more highly pathogenic temporary surface contaminants cannot be too strongly emphasized.

tion in the percentage of superficial mild infections was obtained

3 LIMITING CONTAMINATION BY WAY OF THE LYMPHATIC STREAM

No operation of election should be performed in the zone of lymphatic drainage from an open wound or from a focus of infection. For operations of necessity, if time and conditions permit, any contamination of the lymph drainage and any infection in the distal wound should be reduced and kept to the minimum by appropriate treatment such as free drainage, hot compresses and improved circulation before undertaking the major operation. The least possible compression massage by handling or other trauma should be made about any area of infection and along the course of lymphatic drainage. Needless to say, there should be minimal handling of or damage to the involved lymphatics and the associated lymph nodes.

During the operation care should be taken to avoid unnecessary trauma in the wound itself and to leave the tissues in the best condition for healing and overcoming the bacteria present. An example of this is an amputation performed for an infected gangrenous extremity. If the incision can be made through the region of the knee joint with an adequate blood supply and careful hemostasis, dividing the muscles with minimal trauma in their tendinous portion and closing without tension, the chances of obtaining primary union are better than when the incision goes through the large muscles in the thigh with greater trauma to the soft parts.

4 LIMITING CONTAMINATION BY WAY OF THE BLOOD STREAM

While contamination by this route of sufficient severity to cause suppuration is rare, it undoubtedly does occur and there are certain precautions which should be taken.

Since the operative wound is an area of decreased resistance, it is a favored site for the localization of any organisms which may gain entrance to the blood stream. It is therefore unwise to perform large clean operations at the same time as another operation which might open the blood stream to contamina-

until the time of skin closure. Theoretically and probably actually the contamination from the skin incision could be reduced by using a cutting electric current but the increased damage to tissues outweighs the advantage in any reduction that may be obtained. The tissue so killed must be removed before healing can take place and in the meantime it forms a harbor in which the organisms already present in the skin may multiply more or less protected from the natural body defenses. In actual experience with such an incision on the back in a case of severe acne with a pustular eruption our results were not satisfactory and healing was delayed.

As soon as the operation reaches the stage of skin closure the protecting drapes should be discarded the perspiration should be removed the skin should be treated again with the chemical agent used for the original clean up and fresh sterile drapes should be applied up to the skin edge before proceeding with the closure. Following these precautions the instruments and supplies which must touch the skin will be less likely to carry infection into the superficial part of the wound which remains to be closed.

Some day we may have a *sterile impermeable covering* which will adhere to the skin which will inhibit the growth of surface organisms without acting as an irritant to the skin and through which the incision may be made. We have experimented with such skin coverings but have found none which we consider to be satisfactory. When a thoracoplasty wound is to be reopened for a subsequent operation we have combined an adherent skin covering with gauze and have reapproximated the skin by suturing the gauze thus avoiding skin sutures. The latter act as foreign bodies about which the skin organisms may grow in clusters. These usually do not progress to gross suppuration but occasionally a stitch abscess may form. The resulting increased number of organisms offers a greater threat to the second operation than was present at the first. We have at times used a subcuticular suture of silver wire in order to avoid this source of additional contamination in wounds that are to be reopened and have felt that a reduc-

small particles including bacteria will undoubtedly become more trustworthy and some effective means of sterilizing the air in the ducts as by ultraviolet radiation may come into use. Any of these measures however will require constant attention and then the human error of neglect will come into play.

(b) *Reducing the Number of Bacteria Entering the Air in the Room to a Minimum*—We have found it impossible to prevent some contamination of the air after it enters the occupied operating room. The degree of contamination is influenced by many conditions including the frequency of replacement with clean air as given under (a). Recontamination is slight or absent in the unoccupied room which has little equipment clean painted or tile walls floors that are kept mopped with an antiseptic and with the minimum of dust even if the air is agitated by normal air currents or by means of electric fans blowing against the floor. However during an operation including the period of preparation contamination rises rapidly depending on the number of occupants the degree of their nose and throat and possibly their skin and linen contamination the amount of talking coughing sneezing and hard breathing the effectiveness of the masks worn over the nose and mouth the amount of activity the presence of drafts from other occupied areas the efficiency of the ventilating system and so on. Activity should be kept to the minimum linens including uniforms should be freshly laundered and therefore as free as possible of dust and bacteria and street shoes should not be worn. Infected cases should not be brought into the room used for clean operations though it is doubted if the bacteria from these would get into the air unless they had already dried and were in small particles similar to dust and this should not occur in the well conducted operating room.

It must be kept in mind that the *type of contaminant* in the air is of far more importance than the total number of organisms present. A few highly virulent hemolytic streptococci or hemolytic yellow staphylococci may cause a relatively large number of infected wounds while many white staphylococci gram negative bacilli and fungi may cause no evident damage. This clearly indicates the hazard of admitting car-

tion. An example would be the repair of a hernia at the same time as a hemorrhoidectomy, tonsillectomy, or extraction of a tooth. Furthermore, no patient who has an open wound or who has recently had an infection of any type, particularly if with an associated chill, should have any operation of election, since under such conditions pathogenic organisms may have gained entrance to the blood stream. If under such conditions an operation is imperative, every care should be taken to secure complete hemostasis and to leave the wound in the best condition for the body defenses to overcome the bacteria which may enter. This, however, should be the goal in every operation.

5. LIMITING CONTAMINATION BY WAY OF THE AIR

(a) *Supplying the Room with Large Quantities of Clean Air*—Just as a swimming pool is kept relatively clean by running large quantities of water through it or by circulating the water through a filter which removes the bacteria, so the contamination of the air in the operating room may be reduced by an efficient ventilating system. Forced ventilation with rapid replacement of the air is far more effective in removing the contaminants than the older methods of ventilating by means of open windows.

We have found the outside air in a suburban area to be practically free of pathogenic bacteria, and there are probably relatively few of these present even in the larger centers of population. In our experience the nonpathogenic fungi and bacteria present in the outside air have been removed to a large extent by a well functioning washing and filtering unit in the air conditioning apparatus. The pathogenic bacteria given off by the occupants of the operating room would undoubtedly be removed from recirculated air quite as effectively, but at present it seems to be unwise to recirculate the air, since the air conditioning equipment, particularly if neglected, may fail to remove the bacteria.

Cultures taken in a large number of hospitals showed that the air contamination in the air-conditioned operating room was far less than in the non air conditioned room. With improvements in air conditioning equipment the removal of

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h h m d h d p t l by g d gl

For graphs giving more complete data as to the different intensity distributions and the bactericidal effect of each the reader is referred to the original publication

The most satisfactory intensity distribution that we have used gave a higher intensity in the upper part of the room and a relatively low intensity on the wound and on the heads of the personnel With this the number of colonies surviving on a petri dish of sterile blood agar after one hour of exposure at any point in the operating room at a level of 3 feet above the floor did not exceed an average of one to four colonies the number at any point varying inversely as the radiation intensity In addition to the reduction in the actual number of colonies surviving there was also evidence that the bacteria in the colonies which survived were attenuated

After the various precautions described above with the exception of air disinfection had been put into use we still had a considerable number of wound infections hitherto unexplained With the virtual control of the contamination in the air as a source of these infections not only were deaths from unexplained infections eliminated but such infections of less severity were reduced to an almost negligible number The rare infections that occurred were in general mild Further more patients having wounds which did not go to gross suppuration presented a striking reduction in both the local and systemic reaction

6 LIMITING CONTAMINATION WHEN OPERATING IN THE PRESENCE OF CONTAMINATED MATERIAL OR FOR PRE EXISTING INFECTION

This may be accomplished by one or more of the following means

(a) Wherever possible freshly incised tissues and exposed viscera should be isolated from the operative field and the free spaces and cleavage planes should be packed off before any contaminated material is exposed

This is particularly important in the drainage of abscesses and resection of the intestines Use of *suction* to remove the

appendiceal abscess through an extraperitoneal approach the subdiaphragmatic abscess by the extraperitoneal extrapleural route and the opening of a palmar or thenar space abscess with precautions to avoid damage to the tendon sheaths

(c) If there is a possibility of the contamination being sufficient to cause suppuration the wound may be packed gently with an *antiseptic* to limit further bacterial growth stimulate the walling off process and provide free¹ drainage. Subsequent treatment consists of delayed closure² chemical sterilization and secondary closure or healing by second intention

(d) When it is necessary to approach a focus of infection across a serous cavity which has not been obliterated and at times when we are dealing with an infection at the depths of a large wound made across loosely attached cleavage planes the operation should be performed *in stages*. Time should be allowed for the serous cavity to be obliterated by adhesions the cleavage planes to be sealed off by the inflammatory reaction to a pack and the wound surface to become protected by granulation tissue and the body defense reaction

(e) After contamination has been received it may be reduced as described under (7) which follows

7 REDUCING WOUND CONTAMINATION BEFORE CLOSURE

Contamination in a wound may be reduced before closure by irrigation and washing with a nonirritating solution alone or in the case of traumatized wounds in combination with a thorough debridement. This will be discussed more fully in another section

8 LIMITING THE MULTIPLICATION OF CONTAMINANTS WITHIN THE WOUND

Limiting the contamination of the wound cannot be discussed without giving consideration to limiting the growth of these contaminants after they enter the wound. The patient's general defense mechanism must be maintained at its highest efficiency. The wound itself must be left in the best condition for the body defenses to overcome the invaders so the following conditions should prevail

contaminated material at the appropriate time during the operation may limit soiling of both the isolating packs and the tissues. In a limited number of conditions *continuous aspiration* of the infected material from the bottom of a cavity may prevent the secretions from overflowing into the free spaces or seeping through the operative wound. This is illustrated by the drainage of a fairly rigid walled abscess of the lesser peritoneal cavity following pancreatitis which had been approached through the anterior abdominal wall. The secretions were allowed to drain by gravity to the dependent part of the cavity. As soon as the quantity of secretions was sufficient to cover the holes of a drainage tube attached to moderate but continuous suction the secretions were drawn off so at no time were they allowed to overflow the cavity.

The secretions can be kept thin and removed more effectively by an *interrupted or continuous wash in, out process* if sterile physiologic salt solution is added to the cavity by an appropriate mechanism. However if this treatment is used care must be taken to avoid obstruction of the drainage tube and *flooding of the cavity* before adequate isolating adhesions have formed.

In the case of certain infections in the pleural cavity which necessitate *collapsing operations* as following a pneumonectomy the pus can be drained without leakage about the tube the cavity irrigated and suction applied through a tube inserted with an air tight fit through a minimal intercostal wound in the anterior chest wall. The tube with holes near its tip should extend to the dependent part of the cavity. Subsequently the collapsing operations with their enormous exposure of tissue inevitable trauma and poor hemostasis and residual dead space can be performed in stages in an aseptic field through an incision on the posterior and lateral chest wall. Primary healing with only slight temperature reaction usually follows. A case treated in this way is illustrated in a recent article in the American Journal of Surgery.

(b) Whenever possible during operations that are potentially infected free spaces serous cavities, and cleavage planes should not be opened and the exposure of freshly incised tissues should be limited. Examples are the drainage of an

(c) The *dressings* must not be allowed to become saturated with serum blood perspiration or pus since the organisms gaining access to the surface of the dressings may grow through them to contaminate the wound

(d) *Tension* must be avoided since this causes trauma about the sutures interferes with the blood supply particularly between the sutures and the incision and predisposes to necrosis and bacterial growth

(e) *Maceration of the wound* must be avoided by keeping it dry washing the skin with alcohol and avoiding pressure. Otherwise the growth of the skin organisms about the sutures may form stitch abscesses or extend into the wound to cause more serious infection. Limiting the growth of organisms along the skin sutures is of particular importance in those wounds which have to be reopened since they may be spread through the tissues at the second operation and cause a wound infection. Fortunately such infections are usually mild and superficial

What results can be accomplished by the meticulous and rigorous application of above described principles and precautions? Many of them have been in general use throughout the surgical careers of most of us so we have little personal experience by which to judge. We can however make a general comparison of the operative procedures and results reported before the introduction of antiseptic surgery by Lister the subsequent adaptation of the principles of asepsis and the later emphasis on relatively atraumatic and meticulous surgery as practiced and taught by Halsted and others with the results obtained by the use of these methods today to see what tremendous advances have been made and how well the problem of wound infection has been brought under control

Even with the improvements every surgeon still has occasional unexplained infections in large clean wounds particularly those where trauma is inevitable hemostasis inadequate immobilization impossible and with dead space that cannot be obliterated. These should be a stimulus to all of us to do what we can to eliminate insofar as possible any remaining sources of contamination. Many surgeons feel that there

(a) The incision should be made so as to give the best exposure with the minimal trauma

(b) The blood supply should be intact and adequate

(c) Hemostasis should be complete

(d) Healthy tissues should be in apposition with obliteration of dead spaces

(e) The wound should be immobilized. This is particularly important in so far as any movement between apposed surfaces is concerned

(f) Tension should be avoided

(g) Foreign material should be minimal

(h) Drains and packs should be avoided whenever possible

(i) Sutures and ligatures in addition to being fine should be nonirritating

(j) Tissues should not be strangulated by sutures or ligatures or unduly traumatized by retraction or other parts of the operative procedure

(k) Bacterial growth in the wound may be inhibited by one of the sulfonamides applied locally, given by mouth or injected parenterally. It should be remembered however that the potential gain by their use must outweigh any irritation or other damage that may be produced

9. LIMITING THE CONTAMINATION OF THE WOUND FROM EXTERNAL SOURCES DURING THE POST OPERATIVE PERIOD

Contamination following operation may be limited by the following precautions

(a) *Drums and picks* should be avoided whenever possible and if they cannot be avoided the skin about them should be kept scrupulously clean. They should be covered and surrounded with adequate dry sterile dressings which should be changed as often as necessary to keep them from becoming saturated with secretions. All foreign material possible should be removed from the wound at the earliest moment compatible with the underlying pathology

(b) *Draining hematomas* should be avoided but in case they do occur the surrounding skin must be kept scrupulously clean and the dressings must be changed at frequent intervals

(c) The *dressings* must not be allowed to become saturated with serum blood perspiration or pus since the organisms gaining access to the surface of the dressings may grow through them to contaminate the wound

(d) *Tension* must be avoided since this causes trauma about the sutures interferes with the blood supply particularly between the sutures and the incision and predisposes to necrosis and bacterial growth

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will always be an irreducible minimum of infections which cannot be explained and that this stage has been reached. Others ascribe these infections to *skin contaminants* and such organisms certainly may play an important role in wound infections. This is particularly true in the experience of any surgeon who happens to be a heavy skin carrier of the more pathogenic staphylococci and who as is so commonly the case has frequent punctures of the modern thin glove. Still others have ascribed certain of these infections to the presence of a nose and throat *carrier* (usually of a hemolytic streptococcus) among the personnel. In such cases however they have as a rule not traced the route by which the offending organisms reached the wound.

Much experimental work has been done on masks but in our opinion an adequate and satisfactory form of *masking* has not as yet been perfected. Such an advance may go far toward eliminating the contamination of the air which we consider to be the greatest threat to the large clean wounds in modern well run operating rooms. In recent years there has been much interest in the air as a medium for the transportation of pathogenic bacteria and great contributions to this field have been made particularly by Wells and his co-workers.

Attempts at Reduction of Air Contamination—In 1931 and 1933 when he became convinced that the air was the source of greatest danger in our operating rooms we had considerable difficulty in obtaining the necessary approval of certain changes to be made with the object of reducing the air contamination since it was stated that it has been known since the days of Lister that the air in the operating room can be ignored.

Many measures such as changes in scrubbing more thorough skin preparation of the patient longer sterilization of supplies under greater pressure and isolation of rooms for operations on infected cases had already been put into effect but with no appreciable improvement. In the meantime we had shown that such organisms as the hemolytic *Staphylococcus aureus* could be obtained in greater frequency and in larger numbers from the air than from any other area in the operative field. When these more pathogenic organisms were

present in the air in larger numbers there was corresponding increase in the number of unexplained wound infections caused by the same organism as recovered from the air. Over 90 per cent of the organisms obtained from the air in the operating rooms were staphylococci and 91 per cent of all infected wounds had a staphylococcus (predominantly aureus hemolytic and nonhemolytic) as the etiologic agent.

During the years 1933-35 attempts were made to improve the condition of the air by more efficient and continuous masking by improved ventilation with clean outside air by limiting air currents from other parts of the hospital by limiting the number of occupants and the duration of occupancy by the elimination of known nose and throat carriers of the *Staphylococcus aureus* (hemolytic and nonhemolytic) (which proved to be not feasible because of the large percentage of carriers and the transient nature of the condition for many individuals) and by increased cleanliness of the floors and walls. However the air contamination was found to depend on the number of carriers and the number of these in turn depended on general conditions in the population which were beyond our control. It was found that most of the deaths from unexplained infections occurred during the cooler months when the air contamination was heaviest (Table 1) so large clean operative procedures of election such as extrapleural thoracoplasties were postponed until the summer months with some improvement in results but with serious curtailment of the service because of lack of utilization of available beds throughout the entire year.

Control of Air Contamination by Ultra violet Radiation — Preliminary experiments in killing bacteria at distances up to 8 feet by means of ultraviolet radiation and negotiations with electrical equipment manufacturers for cooperation in equipping a room with this radiation as an experimental project were conducted during 1934 and 1935. These resulted in the clinical application of such air disinfection to operating room technique beginning on January 15, 1936. The ultraviolet radiation (approximately 90 per cent at 2537 angstroms) was used primarily to kill or attenuate the bacteria while they were floating in the air but also to kill within one to five minutes

when the air contamination was high and the least reduction occurred during the summer months when there was a low air contamination

TABLE 2

AN	SO L C C	O	TI	TI	VAR	19 0-140 I	CLU	VE
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RI V	R	Z O	E W	OUT	D W	AIR D	SECTION	
					With t		With	
					Radi t		R d t	
T t l	mb	f	co d	ly ed (all la g	1782		603	
l	p	t)		P C t		I C t	
D th f	m	f	t d w	d	1 07		0 00	
Inf t d		d						
T t l			ly d		11 9		0 28	
Th ra	pl t		l t t b	d d l	32		0 3	
m t	t m				23		6 00	
Th	pl t		b q	t l g	16		0 4	
O th p d	pe i				9 0		0 22	
N	g cal	p rat			1 8		0 00	
Thyr	dect mu				8 3		0 00	
Il m	h ph							

TABLE 3

RE CT	DUR TI V	RE Po	VE T MP	UR I	TI
Y M	V D	PECTI	I U TRAVI	R	O
			P t t H	g T mp t	
			El t t f M	Th 4 D y	
			With t	With	
			R diat	R d t	
			P C t	P C t	
Th	pl t		78	22	
R d	l m t t mu		54	21	
I gu	l h m haphu		46	14	

TABLE 4

R	CTI V	THE I	ATIVE T MP R	URE ELE	TI	M	AIR
		D	TI W TH U	RAD			
					P t t H vi R I t p t		
					T mpe t l t t bo		
					38 C (100 4 F)		
					With t	With	
					R diat	R d t	
					P C t	P C t	
E trapl	l th	racoplast es			68	30	
R d	l m	tect mu			46	34	
I gu	l h m	h plu			36	2	

When air disinfection was used the highest and longest postoperative temperature reactions occurred during the sum

mer months when contaminated perspiration may have played a part in wound contamination in contrast to the results when air disinfection was not used when these temperature reactions were greater during the winter

From these results it can be seen that by adequate control of the contamination reaching the wound and sterile supplies by way of the air we have been able to eliminate the deaths from unexplained infections greatly reduce the percentage of such infections and also reduce the local and systemic reactions in those patients whose wounds did not go on to gross suppuration

Another gain of the greatest importance to the staff but one which cannot be put down in table form has been the restoration of their confidence in the effectiveness of aseptic technique and the assurance that large clean operations of election can be performed at any time of the year without undue risk of infection

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ACCIDENTAL WOUND INFECTIONS

ALFRED B LONGACRE M D †

THE tremendous loss resulting from accidental injuries is almost inconceivable to the human mind. Major catastrophes such as war between nations, tornadoes, earthquakes, conflagrations and floods with their concentration of injury merely suggest what this loss might be. Modern civilization with its increased tempo of living has unfortunately added to the number and severity of human accidents to the point where they must be considered part of the expense of our progress. Realization of this fact makes obligatory the taking of measures to minimize the frequency of complications resulting from these accidents. One of the most serious and costly complications which adds either to the total loss of life or to the numbers of totally disabled is infection superimposed upon these wounds. If such infections could be eliminated or significantly reduced in numbers by either prophylactic or active treatment, not only would the extent of human suffering be alleviated but the savings in money, time and man power would also be incalculable.

WOUND HEALING

The ultimate achievement in the treatment of accidental wounds is a healed wound without complications and with restoration of normal anatomy and physiology. In many instances the pathologic processes resulting from the trauma as well as from numerous secondary sources precludes the possibility of attaining this result. However every physician and surgeon handling such cases should constantly keep in mind this objective and endeavor to approach as closely as

† r m th D p rtm f S g ry S h l f M d T l U
rs y N w O l
† l tru S rg ry Sch l f M d Tul Un rs ry

possible this goal in any specific case. In order to accomplish this those treating such cases should be familiar with the fundamental principles of wound healing as well as with the factors which predispose to infection. Neglect to adhere to these concepts may seriously jeopardize not only the healing of the wound and restoration of function of a wounded part but may also result in sepsis which might even endanger the patient's life.

It has often been stated that the three discoveries *hemostasis*, *anesthesia* and *asepsis* are responsible for surgery as it is practiced today. Reid, in discussing wound healing, states:

Believing that it is erroneous to give students and young doctors the idea that the problem of wound healing is essentially synonymous with the principles of asepsis and antisepsis, we have deliberately fostered the idea that modern surgery owes its very life to anesthesia, the control of hemorrhage and to a better knowledge of wound healing. It has been apparent during the history of medical research that investigators in focusing their attention upon the immediate problem often lose perspective and consequently fail to integrate properly their observations with already existing knowledge. Reid and Stevenson have aptly expressed this in relation to wound healing as follows: To utilize effectively all knowledge of fresh wounds and their healing is difficult because overemphasis of one fact in therapy so readily leads to the sacrifice of other important factors. The relative importance of the several principles to be observed in the treatment of wounds should not be compared for neglect of any one might decrease the possibilities of attaining the best results. One of the most serious complications of a healing wound is that of infection which in itself is capable of nullifying the surgeon's efforts.

Rigid adherence to the principles of asepsis in the treatment of accidental wounds is not sufficient in itself to insure healing without complications. Wound complications in the absence of sepsis undoubtedly delay wound healing and may even result in a partial or total loss of function, but they do not carry with them the constant threat of more serious complications, both local and metastatic, which septic wounds possess.

BACTERIOLOGY OF ACCIDENTAL WOUNDS

For an accidental wound to become complicated by infection two conditions must be present (1) pathogenic bacteria must gain access into the wound (2) the conditions of the wound must be such that these bacteria find a favorable environment for their growth and the production of their toxins. In the treatment of an accidental wound efforts should be directed toward the elimination of either one or both of these conditions.

A. All W d C tam t d?

Innumerable reports²⁸ that infection occurs in from at least 3 to 5 per cent of clean surgical wounds is evidence that even under rigid aseptic technique it is still impossible to prevent pathogenic bacteria from entering these wounds. Ives and Hirschfeld in a study of bacterial flora of clean wounds found that bacteria were present in the wound in 86 per cent of the cases immediately after incision of the skin and present in 100 per cent of the cases just before closure of the skin at completion of the operation. The findings in an earlier investigation by Hunt were similar. The sources of these bacteria are familiar and precautions designed to minimize their significance constitute a part of the accepted routine of rigid aseptic technique.

Several investigators have reported wound bacteriologic studies of which failed to demonstrate the presence of bacteria. Veraart and Drenth report that 41 per cent of the 15 wounds investigated by them were sterile. While Dintzis and Gutscher report that they failed to grow bacteria from approximately 17 per cent of 424 wounds cultured. Miles and associates cultured wounds infected in combat and during air raids. They failed to grow organisms from some of the wounds which were first cultured as long as twelve days after the injury and were unable to demonstrate the presence of bacteria in 87 per cent of forty-six wounds all of which were cultured between the first and third day after injury. In another series of fifty-four wounds which were first cultured between four and twelve days after the injury 11.1 per cent were bacteria free.

Contrary to these reports which seem to indicate that there might be many accidental wounds which do not become contaminated are numerous other studies definitely suggesting that all accidental wounds are contaminated. Sas studied bacterial flora of fifty five accidental wounds and concluded that such wounds are always contaminated and are potentially more serious than clean operative wounds in that they are frequently contaminated with organisms of the gas gangrene group. Pulaski and associates made a detailed analysis of the bacterial flora in 200 accidental wounds and found bacterial contamination present in all of them. Consideration of the multiple sources from which contamination of accidental wounds can occur would appear to make contamination of every wound logical. The failure to obtain growth in some wounds probably could be accounted for by the inadequacy of technical detail either in taking the specimen or in the method of culturing them.

The sources of bacteria which contaminate accidental wounds are manifold any exhaustive list of which would still be incomplete. The particular species of bacteria which may be recovered from accidental wounds will vary according to their source. It has been fairly well established that staphylococci and streptococci are the most frequent contaminants of wounds and consequently are the most common etiologic organisms of a resulting infection. This is compatible with the observations of Meleney and Stevens, Devenish and Miles, Ives and Hirschfeld, Gillespie and associates, and Price.

They have shown that these organisms particularly the staphylococcus constitute part of the regular flora of the skin and that they are also harbored in respiratory passage in 0 to 30 per cent of apparently normal individuals.

Aerobic Pathogens

Aerobic pathogens other than those of the streptococcal and staphylococcal groups have been recovered both from contaminated accidental wounds and from infected accidental wounds both in pure culture and as a mixed flora. However the frequency with which these other pathogenic organisms is considerably lower and certain species have been

recovered rarely. The significance of nonpathogenic or saprophytic organisms contaminating a wound in conjunction with a known pathogen is not clear. It is conceivable that in this symbiosis the pathogenicity of the pathogens may be either augmented or decreased. Consequently even though these saprophytes have little or no significance their presence should not be totally disregarded.

A b c P t h g e s

Organisms of Gas Gangrene—The high incidence of gas gangrene in the wounded during the early years of World War I emphasized the importance of anaerobic bacteria as etiologic agents in the infection of wounds. The morbidity and mortality resulting from infection caused by the anaerobes of the clostridium group as compared to that resulting from the more common aerobes are sufficiently greater to make significant their relatively low incidence. The full realization of this fact resulted in concentrated studies of wounds and the conditions which favor the development of these particular types of infection. Application of the knowledge gained by the investigation was followed by a reduction in incidence of gas gangrene occurring in the B E F from 17 per cent in 1914 to 1 per cent in 1918.

That these organisms contaminate wounds more frequently than reports on the incidence of gas gangrene would lead one to believe is attested to by studies of Zeissler and Neller. Sas, Levaditi and associates, Pulaski and many others. Pulaski observed that the frequency with which he was able to recover clostridia from accidental wounds varied directly as the time between the inception of the wound and its culturing. This figure would at first appear to disagree with the observations of Miles and associates² on soldiers and air and sea casualties in England in that they found the frequency with which these organisms were recovered decreased as the interval increased. More careful scrutiny shows that further work needs to be done for Miles' period of time was calculated in days while Pulaski calculated the interval in minutes elapsing the longest period being only one hour. While in England recently I was fortunate enough to be able to discuss

Contrary to these reports which seem to indicate that there might be many accidental wounds which do not become contaminated are numerous other studies definitely sustaining that all accidental wounds are contaminated. Sas studied bacterial flora of fifty five accidental wounds and concluded that such wounds are always contaminated and are potentially more serious than clean operative wounds in that they are frequently contaminated with organisms of the gas gangrene group. Pulaski and associates made a detailed analysis of the bacterial flora in 700 accidental wounds and found bacterial contamination present in all of them. Consideration of the multiple sources from which contamination of accidental wounds can occur would appear to make contamination of every wound logical. The failure to obtain growth in some wounds probably could be accounted for by the inadequacy of technical detail either in taking the specimen or in the method of culturing them.

The sources of bacteria which contaminate accidental wounds are manifold any exhaustive list of which would still be incomplete. The particular species of bacteria which might be recovered from accidental wounds will vary according to their source. It has been fairly well established that staphylococci and streptococci are the most frequent contaminants of wounds and consequently are the most common etiologic organisms of a resulting infection. This is compatible with the observations of Meleney and Stevens, Devenish and Miles, and Hirschfeld, Gillespie and associates, and Price who have shown that these organisms particularly the staphylococcus constitute part of the regular flora of the skin and that they are also harbored in respiratory passage in 70 to 80 per cent of apparently normal individuals.

Aerobic Pathogens

Aerobic pathogens other than those of the streptococcal and staphylococcal groups have been recovered both from contaminated accidental wounds and from infected accidental wounds both in pure culture and as a mixed flora. However the frequency with which we see these other pathogenic organisms is considerably lower and certain species have been

recovered rarely. The significance of nonpathogenic or saprophytic organisms contaminating a wound in conjunction with a known pathogen is not clear. It is conceivable that in this symbiosis the pathogenicity of the pathogens may be either augmented or decreased. Consequently even though these saprophytes have little or no significance their presence should not be totally disregarded.

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this problem with Miles. He stated that he could account for the decrease in the frequency with which he recovered *Clostridium welchii* from wounds on the theory that in those cases which had not developed gas gangrene within the first forty-eight to seventy-two hours the patient developed a resistance to this infection and that the persistence of the organism in cases of long standing indicated a mere saprophytic existence. It has been shown that even though *Clostridium welchii* can be recovered in from 85 to 100 per cent of the cases of gas gangrene there are other gram positive spore forming anaerobes of this same genus capable of causing this disease.

The actual incidence of gas gangrene is considerably lower than one would be led to believe by the frequency with which these organisms are found in accidental wound. Cramp in 1917 found only nine cases of gas gangrene in a series of 5807 traumatic injuries admitted to Bellevue Hospital. Burnett studied the number of hospital admissions in two widely separated but comparably similar rural communities and found the incidence of gas gangrene to be 0.1 per cent and 0.25 per cent in these hospitals. Stone and Holsinger reviewed 6934 cases at the University of Virginia Hospital and found only sixty-seven cases of gas gangrene an incidence of 0.09 per cent. From these figures it would appear to be reasonable that the incidence of gas gangrene in civilian life probably varies between 0.1 and 0.25 per cent.

Clostridium Tetani—The reported low incidence of tetanus compares directly with the frequency with which its etiological agent has been recovered from accidental wounds. Wright in an analysis of over a million industrial accidents found the incidence to be 0.0008 per cent. Sir David Bruce found the incidence to be 0.117 per cent in over a million wounded British soldiers. Weed found the incidence to be only 0.2 per thousand in a total of 176,135 battle wounded in the American Expeditionary Force of World War I. This figure showed considerable improvement in the comparison with the figure observed in the B.C.F. of 1.7 per thousand.

The figure of 1.7 per thousand is

wounded at the beginning of the war. Figures on the incidence in civilian population are somewhat misleading and do not indicate the incidence of tetanus occurring as the result of accidental wounds. These reports usually include all cases of tetanus some of which have resulted from such conditions as smallpox vaccination hypodermic injections lung abscesses and even clean surgical cases. However Nicoll found that in a period of nineteen years 1683 cases of tetanus deaths in New York City had occurred and also that the death rate had consistently fallen from 1.49 per cent per 100 000 population to 0.04 per 100 000 in 1925. Reports on the bacterial flora of accidental wounds show that the *Clostridium tetani* has been recovered very rarely which would seem to prove its relative infrequency in such wounds. However in many incidences because of inadequate bacteriologic methods the identification of these organisms had they been present would have been impossible. In one of the most detailed studies of the flora of bacteria in wounds Pulaski failed to find this organism in any of the 100 wounds studied.

Organisms of the Mouth—The bacterial flora in wounds contaminated with organisms of the mouth will undoubtedly be mixed and contain both aerobes and anaerobes as well as those associated with the fusiform and spirochetel group. Case record of the malignancy of infections resulting from human bites are testimony of the imminent dangers of wounds contaminated with these organisms. Whether or not any species or strain of micro-organism and whether or not it is the symbiotic action of the various species present which is responsible for the virulence of these infections has not been determined. Realization of the significance of the anaerobes in infection of these wounds appears to be increasing.

Aerobic Streptococci—The pathogenicity of anaerobic streptococci in wound infections has as a result of investigations by Meloney recently gained added significance. A fairly careful review of the literature failed to reveal any report indicating that these organisms are of etiologic significance in the development of acute wound infection. This does not mean that anaerobic streptococci are not the responsible

agents of such infections Pulaski⁵ recovered anaerobic streptococci in twenty two incidences thus establishing the fact that these organisms do contaminate accidental wounds

More recent studies of anaerobic bacteria suggest that certain species of gram negative anaerobes might have an etiologic significance in the development of wound infection. However as these organisms have been recovered very rarely from infected wounds further discussion other than to emphasize the etiologic possibilities will be omitted

DIFFERENCES BETWEEN CONTAMINATED AND INFECTED WOUNDS

The savants of wound healing have attempted to differentiate between the contaminated and the infected accidental wounds on the basis of the *time interval* elapsing between the inception of the wound and its presentation for adequate therapy. This time interval varies somewhat with the location and nature of the wound as well as with variation in the types of bacteria which were introduced at the infliction of the wound. The discrepancy of opinion of the various investigators as to the length of this time interval is evidence that multiple factors must be considered in its establishment. It is impossible to determine by any set measure of time the moment at which a contaminated wound becomes transformed into an infected one. Opinion varies from two to twenty four hours depending upon the criteria of the individual investigator. The majority of the investigators express their opinion that in a relatively clean laceration or wound this transformation will not occur before a lapse of six to eight hours.

Factors definitely shortening this time interval must include the location of the injury which at times will interfere with an adequate debridement especially if vital structures must be sacrificed the extent of obvious gross contamination the extent of the injury and whether or not the contamination contains organisms which at the time of their introduction either had come from human sources or had been adapted to the environment of human tissues. In addition to these there are several other factors such as the treatment which the wound receives prior to being treated by the surgeon the

general condition of the patient and the existence of systemic disease such as diabetes and tuberculosis all of which predispose toward infection. It is therefore impossible by any measure of time to differentiate between contaminated and infected wounds in any individual case. Each should be judged by its own merits. However as a general rule it might be said that the likelihood of this transformation having already occurred increases tremendously after a four hour period and that every case of more than eight hours duration between inception and treatment should be considered infected and treated accordingly.

PRINCIPLES OF FIRST AID

It is the period between the time of the injury and that at which adequate treatment can be instituted when additional contamination and trauma may increase the likelihood of the complication of infection. Instructions in first aid manuals are for the most part concerned with the prevention of this added trauma and contamination. In brief there are three main points which should be emphasized and these are (1) the control of dangerous or profuse hemorrhage (2) the simple covering of the wound or wounds with a sterile dressing and (3) rigid immobilization of any injured part. Careful adherence to these three principles will for most wounds reduce the possibility of further contamination either gross or microscopic and will definitely diminish the risk of adding trauma to that already inflicted. Probably one of the greatest sources of danger in the treatment of these injuries lies in the attempt to do too much under inadequate conditions in first aid and dressing stations. With the exception of the most trivial wound it is suggested that if it is at all possible actual treatment be delayed until it can be carried out in an adequately equipped operating room under rigid aseptic technique.

PRINCIPLES OF TREATMENT

Reid and Carter Mason² Koch and many others³⁻⁵ have repeatedly emphasized and stressed the important points to be observed in the treatment of accidental wounds. Adherence to their principles will undoubtedly create an environ-

ment which is most favorable to the healing of the wound without complications. These points include (1) rigid adherence to aseptic technic (2) control of hemorrhage (3) extensive debridement (4) avoidance of introduction of anything which will be harmful to living cells (5) maintenance of adequate blood supply to the tissues (6) a conception of the significant differences existing between a contaminated and infected wound (7) the importance of granulation tissue in the healing of a wound and (8) a realization of the fact that the actual healing of the wound is a biological process dependent upon the proliferation and activity of living cells. The technic necessary to cover all these principles has been very clearly and adequately presented and all surgeons who are treating such wounds should be familiar with them.

CARREL DAKIN AND RELATED METHODS

The high incidence of infection during the early years of World War I stimulated the investigation of the responsible factors and the development of more adequate method for their prevention and treatment. Out of this war emerged the Carrel Dakin treatment which was responsible for a tremendous relief from suffering and a marked reduction in existing morbidity and mortality. Its early successes were attended with unbounded enthusiasm which in the succeeding years has been somewhat dimmed by its failure to accomplish the manifold duties demanded of it. The three major disappointments of the Carrel Dakin treatment resulted (1) in the demonstration that its penetrating powers were insufficient to exert a bactericidal effect on bacteria other than those on the surface of the wound (2) its instability which made necessary the use of fresh preparations and (3) its transient action which required frequent reapplication in order to make its possible beneficial effects surpass the possible harm. At present Dakin's solution is still quite widely used as a chemical debriding agent.

During the third decade of the twentieth century numerous antiseptics were introduced. Definite bactericidal and bacteriostatic properties were claimed for all of them both by *in vitro* and *in vivo* experiments. Various claims of being non

irritating to living cells were made for each of the antiseptics. The enthusiasm of the protagonists of these various antiseptics has been generally unwarranted in that the vast majority of them have been proved incapable of sterilizing the wounds and possess definitely irritating properties which have been shown to interfere with normal wound healing. Consequently the present trend in the treatment of accidental wounds has once more returned to the physiological methods which depend to a large extent upon the mechanical removal of foreign material, bacteria and dead and devitalized tissue. Isotonic salt solutions and debridement when used both in sufficient quantities and in the hands of a well trained surgeon have proved adequate to accomplish this end in a large percentage of cases.

TOILET OF THE WOUND

The importance of a careful toilet of the wound as described by Reid, Mason, Koch, Meleney and others cannot be overstressed. It undoubtedly constitutes the surgeon's front line of attack and the patient's first line of defense in the prevention of infection of an accidental wound. The details of the technic of an adequate and thorough debridement have been stressed by others and should need no further comment.

Regarding the criteria as to whether or not the wound should be closed or left open and whether or not structures such as severed tendons or nerves should be repaired immediately or wait for a secondary procedure there seems to be some disagreement. All are agreed that no wound which has changed from a contaminated to an infected wound should be closed. Meleney feels that this may occur within two to three hours after the inception of the wound while others including Koch, Reid and Mason feel that the change in bacterial flora which makes a contaminated wound an infected wound probably is not sufficiently advanced to interfere with the suture of tendons or nerves until four hours after the injury and that probably it is safe after careful debridement to close the wound up to six hours. Bunnell on the other hand feels that in a clean laceration which has not been rimpered with tendons can be

ment which is most favorable to the healing of the wound without complications. These points include (1) rigid adherence to aseptic technique (2) control of hemorrhage (3) extensive debridement (4) avoidance of introduction of anything which will be harmful to living cells (5) maintenance of adequate blood supply to the tissues (6) recognition of the significant differences existing between a contaminated and infected wound (7) the importance of granulation tissue in the healing of a wound and (8) a realization of the fact that the actual healing of the wound is a biological process dependent upon the proliferation and activity of living cells. The technique necessary to cover all these principles has been very clearly and adequately presented and all surgeon who are treating such wounds should be familiar with them.

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During the third decade of the twentieth century numerous mercuric antiseptics were introduced. Dimethylmercuric chloride, with its bacteriostatic properties, was chosen for all these studies in vitro and in vivo experiments. Various claims of bene-

ment of these drugs either prophylactically or therapeutically will remain somewhat empirical until bacteriologic studies of a specific wound reveal the presence of a particular species of bacteria against which these drugs have been proved to be effective or until future investigations show that sulfanilamide or one of its derivatives is effective against all bacteria which might contaminate a wound.

The present military conflict as well as the preceding Civil War in Spain presents surgeons with a wealth of material upon which to try these compounds. The proof that sulfanilamide and its accepted compounds exert a definite prophylactic and therapeutic effect against streptococcus plus the evidence that sulfathiazole and sulfadiazine possess some bacteriostatic if not bactericidal properties against the staphylococcus seemed justification for their extensive use in the treatment of war wounds. Unfortunately the very size of the organization required to insure the maximum in treatment to the greatest number is such as to prohibit adequate observation of the cases by any one competent observer. This results in the loss of much valuable information which if it could be salvaged would give a firmer basis for knowledge than the results which are repeatedly appearing in the literature. It would seem therefore that any evaluation of the benefits derived from these drugs based on the results must await further and more detailed studies to confirm or disprove the impressions. If we use these reported figures as an index of the incidence of infection when compared to similar reports obtained from the wounds inflicted during the last part of the World War I they show a marked improvement. This would seem to indicate that whether or not sulfanilamide or one of its derivatives is the responsible factor the methods in handling these wounds are superior to those used in the first World War.

Experimental and clinical evidence that these drugs are effective against streptococcal infections is abundant and some of the newer derivatives are being found to exert some bacteriostatic or bactericidal action against the staphylococcus. More recent investigations both in America and in England indicate that direct immersion of the crystals of sulfanilamide

sutured safely as late as twelve to twenty four hours after the injury

From an analysis of the various discussions as well as judging from some of the results in my own cases it would seem that Meleney¹ is perhaps ultraconservative and that he must leave many wounds open which could have been safely closed thus avoiding a prolonged convalescence. On the other hand it would be very poor advice to recommend that it is safe to treat this factor of potential infection as Bunnell apparently does. In his hands it may be perfectly safe to suture tendons as late as he says but I do not believe that his results could be duplicated by many other surgeons. Probably the middle course of six to eight hours should constitute the upper limit of elapsed time between the injury and institution of a definite therapy within which a wound may be safely closed.

CHEMOTHERAPY OF WOUNDS

The Sulfamide

More recently the surgical profession has been presented with two new types of chemotherapeutic agents for both of which enthusiastic claims are now appearing in the literature. The benefits to be derived from the judicious use of sulfanilamide or one of its accepted derivatives have been reported with increasing frequency. Colebrook⁴³ in 1936 in a presentation of the therapeutic possibilities of these compounds, limited his discussion to his actual experiences with promptly in combating puerperal streptococcal infections. His greatest fear at this time was that as this drug gave so much promise enthusiasts would not only report inadequately controlled and studied series of clinical and laboratory investigations but would also tend to make claims for the drug without sufficient evidence to back them up. Even though the results of further experiments have proved that the scope of effective action has not only surpassed the early indications but has been extended in almost a limitless fashion to include many species of bacteria considerably more controlled investigation and work needs to be done to establish the position in regard to the effectiveness of their action against certain species of bacteria. As the flora of accidental wound may be leg on the employ

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or one of its derivatives into a wound might be of benefit in reducing the complications. Tendler, Key and associates, Campbell and Smith, and Jensen and associates report a lower incidence of infection in their series of traumatic wounds. They refer to a series of cases treated in the pre-sulfanilamide era as controls which form the basis upon which they judge these results. It would have been more conclusive if this comparison could have been made between a group of controls treated at the same time.

The local implantation of sulfanilamide in debrided wounds is being extensively used in the treatment of accidental wounds in war-torn England. However, here again except for a few isolated investigations much of the pertinent data will never be recorded and once again the results will be reported merely as impressions and should be considered so. As sulfanilamide is very slowly absorbed from the surfaces of the wounds, the rationale for this form of therapy depends on the fact that in spite of the large amounts implanted, the blood concentrations will be very low, thus minimizing the possibilities of untoward reactions while maintaining a high local concentration. This local concentration has been observed to be as high as 600 to 1000 mg. per cent while the blood concentration has remained well within limits which should not increase the likelihood of systemic reactions. Key and associates also demonstrated by results of their studies on animals that this high concentration was not detrimental to wound healing. This latter observation needs further experimental investigation for it has been repeatedly observed that the wounds into which these drugs have been introduced are for the first forty-eight to seventy-two hours afterwards considerably more moist than those which have not been so treated.

Since the introduction of the sulfonamides, enthusiasts have made various claims for their action against different species of bacteria. Many of these claims have been justified, but others are open to serious doubts. Particularly the claim of their effectiveness against the organisms of the clostridial group. The importance of the use of other drugs in the treatment of gas gangrene has been collected and analyzed to show that in the collected series not only are the results insuffi-

cient to establish the diagnosis in many of the cases reported but that also the results are no better than in previously reported series which did not have the benefits of these drugs. However as to their prophylactic properties in the treatment of accidental wounds contaminated with organisms of this group there is increasing evidence that sulfathiazole and sulfadiazine possess a very definite bacteriostatic property and thus prevent the development of an incipient infection.

Following the suggestion of surgical group at Tulane Cox and others are at present studying the effect on the incidence of infection of local implantation of sulfanilamide crystals into a wound as a part of *first aid therapy*. Experimentally it has been shown that the shorter the time interval between the contamination of the wound and the introduction of sulfanilamide into the wound the greater protection this drug affords. The first aid treatment in no manner should substitute for therapy however indications are that if this drug is introduced immediately into a wound its bacterial inhibiting action may permit a slight increase in the time interval between the contamination and infection of the wound.

Zinc Peroxide

Since the introduction of zinc peroxide as an effective dressing in combating the microaerophilic and anaerobic streptococci this dressing has been applied with benefit in the treatment of wounds infected with other anaerobes. Meleney has reported on its use in the treatment of neck abscesses infected with the mouth flora in the treatment of badly contaminated accidental wounds and in the treatment of gas gangrene. In view of the high incidence of contamination of accidental wounds with various pathogenic strains of anaerobic bacteria the use of zinc peroxide has a very definite place in the treatment of those wounds which for various reasons have to be left open. As zinc peroxide is not absorbed and may as a result exert a foreign body action if not removed it should not be used in a wound which is to be closed or in the one which because of sinus tracts or other conditions, might make its removal by gentle irrigation impossible.

The dramatic results which have followed the investigations

of the sulfonamide compounds have overshadowed the development of zinc peroxide. As the limitations of the range of effectiveness of the former drugs is being more sharply defined especially in the treatment of certain anaerobic infections further studies of other forms of therapy in these infections either as an independent type of treatment or in conjunction with the sulfa compounds are indicated. On the basis of present evidence the combination of zinc peroxide locally and sulfa compounds systemically or both combined locally would appear most effective.

CLOSED PLASTER TREATMENT OF WOUNDS

Probably one of the major contributions to the treatment of accidental wounds resulting from the recent wars has been a wider application of the principle of the closed plaster method of treatment of these wounds. The reports of Trueta and others indicate that this method of treatment has probably been an important factor in lessening the incidence of serious infection and thus decreasing the morbidity and mortality of wounds obtained in both the Spanish Civil War and the present World War. However in a conversation which I had with Trueta he stressed the importance of an adequate debridement and preparation of the injured area prior to the application of the plaster. He also pointed out that to obtain maximum benefit from this method of treatment the immobilizing plaster cast must be applied in such a manner as to obtain complete immobilization of the injured part. It is also important that changes of plaster be very infrequent. Trueta does not consider a rising temperature a common reason for a gland uncomfortable cast due to swelling and moderate pain as indications for change of plaster. He definitely feels that even in the presence of these signs removal of plaster only makes the prognosis worse.

The technique in brief in the application of this plaster follows. After a careful debridement the wound is left open and loosely packed with sterile absorbent gauze. A circular plaster is then immediately applied directly over the skin and wound; this plaster is left in place for various intervals of time from ten to six weeks or even longer disregarding

many of the usual previous indications for changing the dressing. Recently powdered sulfanilamide or one of its derivatives has been introduced into the wound following debridement and prior to the application of plaster. The change of the plaster is carried out with the usual observance of aseptic technique and with precautions to minimize motion of the wound at this time.

This method of treatment and its advantages are not new. The importance of *rest* in the healing of the wound has long been known, the fact that *immobilization* decreases pain and thus tends to minimize the dangers of secondary shock as well as definitely to increase the sense of well being of the patient is not new. That *frequent dressings* of a wound not only increase the risk of secondary infection with each dressing but also is accompanied by a certain amount of trauma which may retard the healing of the wound has been previously demonstrated. The problem of *cross infection* which has been associated with dressing wounds on hospital wards has once more been shown to be of real significance. McHisscock and associates have found the incidence of cross infection to be very high in the wounds resulting from this war. The advocates of this closed plaster method of treatment of these wounds feel that it not only incorporates all the principles of rest and relief of pain but also minimizes the dangers attending frequent dressings of the wounds.

As with other forms of therapy *contraindications* to the use of closed plaster method of wound are to be considered. (1) It would seem inadvisable to apply a closed plaster to an incipient or established cellulitis. (2) Closed plaster in the face of active gas gangrene is definitely contraindicated. (3) For any wound which for any reason cannot be properly debrided the closed plaster treatment would probably definitely increase the risk of infection. (4) The improper application of plaster for any condition is to be discouraged. (5) If the plaster cannot be applied so as to secure complete immobilization of the soft tissues it will not accomplish its purpose.

The *physiologic principles* underlying this method of treatment are not completely understood. Barnes and Trueta have experimentally demonstrated on dogs that the simple

application of a plaster to an extremity decreases the rate of flow of lymph. They feel that this fact probably explains the infrequency of systemic reaction even in the presence of supuration. This contention is incompatible with the existing conception that edema fluid which predisposes to infection is drained by the lymphatics. It would seem that if this were so any mechanism tending to decrease the rate of lymph flow draining an injured edematous area would not only increase the edema but should also increase the frequency of infection. The reports of the wounds treated in this manner show that the incidence of infection is considerably lower. Consequently, other factors attending this method of treatment probably are responsible for the benefits attained.

Even though it is impossible at present to evaluate completely the closed plaster method of treatment of accidental wounds it should be considered only as an adjunct in the treatment of wounds. Along with the other points of treatment which have been mentioned plaster is only a step of the process in creating an environment favorable to the healing of a wound without complications. Further use of this method under controlled conditions should establish its true position. At present the clinical reports indicate that since its application to the treatment of wounds the incidence of complication, morbidity and mortality has been markedly decreased.

PROPHYLAXIS

The problem of accidental wound infection should be one of prophylaxis and not the treatment of an infection. Unfortunately, infection is already present at the time when many of these wounds are first seen by the surgeon. In this group there is no recourse other than the treatment of the existing condition. Fortunately, the majority of the wounds are amenable to prophylactic treatment. It has been shown that the introduction of bacteria pathogenic and nonpathogenic is inevitable. Consequently, the prevention of infection is almost the entire responsibility of the physician or surgeon attending the case. This responsibility consists of application of the existing knowledge of wound healing and of measures to minimize the risk of infection. As the etiologic agents of

infection are already present treatment should be directed toward creating an environment unfavorable for its development. With this objective in mind and careful adherence to the technic necessary for its execution the consequences of wound infection will decrease as does its incidence.

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INFECTIONS OF SKIN AND SUBCUTANEOUS TISSUE

HAROLD D. HARVEY, M.D.

THE organisms which cause infections of the skin and subcutaneous tissues may enter from outside the body as by a needle prick from the skin glands from structures beneath the deep fascia or by way of the blood stream and lymphatics. It is usually easy to decide in any lesion which was the probable route of entrance and it is important to do so in order to avoid oversight of a possible deep infection from which pus has escaped through a narrow channel in the deep fascia to mushroom out in the subcutaneous fat or form a pus blister in the skin.

While it is possible for almost any pathogenic organisms to be found in superficial infections especially in wounds that involve hollow viscera, most infections arising beneath grossly uninjured skin are caused by some form of staphylococcus or streptococcus and to these most of this paper is devoted.

INFECTIONS CAUSED BY STAPHYLOCOCCI

SUSCEPTIBILITY—*Furuncles* and *carbuncles* rank perhaps with the common cold as afflictions renowned for their frequency and for the lack of progress made by the medical profession in prevention and treatment. Certain facts about local staphylococcal infections are known to the laity almost as well as to physicians. Some people are susceptible to them all their lives while others are practically immune. They are apt to appear in adolescence as for instance in relation to acne and hematogenous osteomyelitis. In the case of furuncles periods of susceptibility may be interspersed among periods of intermittent immunity. Among diabetics they may be more frequent or perhaps merely more severe and therefore more noticeable than among nondiabetics. They may be produced

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by rubbing staphylococci into the skin or by slight trauma such as pulling out a hair or by the presence of ingrown hairs. They may appear beneath adhesive plaster. They may at times be associated with lack of cleanliness. They are thought at times to appear in people because they are run down but they also appear frequently among athletes apparently in good training. Some of these factors are readily explained as local trauma or as interference with normal excretion from the skin but we can say little about the underlying individual or periodic variations in susceptibility among people except that they seem to exist even if no reliable method of measuring them has been found.

PATHOGENICITY OF STAPHYLOCOCCI—Although so little is known about factors that constitute susceptibility on the part of the host, some knowledge is accumulating about the characteristics of the causative organism. Blair⁴ has reviewed the literature on staphylococci and reports the following findings. Some pathogenic strains (about 85 to 90 per cent) produce *in vitro* demonstrable *antigenic exotoxins*. These include the so-called lethal toxin which can produce death when injected into animals. At autopsy, these animals show non-specific lesions such as are associated with acute intoxications. There are also a dermonecrotxin, a hemotoxin, a leukocidin and an enterotoxin. None of these toxins has been isolated from the others and they may all be actually one. The filtrate from pathogenic staphylococci in culture usually has the power to coagulate human plasma and to dissolve fibrin. It is possible to produce a staphylococcus *toxoid* that is a toxin which has lost all or nearly all of its reactive properties but retained its antigenic properties. Such toxoids are produced commercially. *Antitoxins* can also be produced and the Committee on Standards of the League of Nations has established qualifications for an international standard staphylococcal antitoxin titrated for its ability to inhibit hemolysis and necrosis or the lethal action. The ability to coagulate plasma Blair believes is the best laboratory evidence of pathogenicity of a strain as weakly pathogenic strains in general do not produce coagulum nor do they ferment mannitol as the pathogens do.

Farrell has carried further the study of the toxins having found 600 strains of pathogenic staphylococci from human sources which produced diffusible toxins *in vitro*. He distinguishes between the power of staphylococci *to invade* and their power *to produce toxin*. To the former he attributes the deaths which occur irregularly in a series of mice injected with relatively small doses of the organisms while to the latter he attributes the deaths which regularly occur when doses as large as five average lethal doses are injected. Staphylococcus antitoxin he found neutralized the toxic effect of toxigenic strains but did not appear to alter the power of invasion.

PREVENTION—The foregoing practical and experimental facts give a rational basis for measures of prevention for people who are susceptible to staphylococcal infections. *Trauma* such as pulling hairs from the nares, the wearing of chafing dirty clothes or the habit of rubbing or fingering the face may be avoided. One may institute special measures for *cleaning the skin* especially of the face and neck. Dressings of abscesses may be held in place by small dabs of liquid adhesive or no adhesive at all. A *restriction of carbohydrates* even in the absence of demonstrable elevation of the blood sugar may be beneficial. Prophylactic subcutaneous injections of *staphylococcus toxoid* may be given twice a week beginning with 0.1 cc. and increasing by 0.2 cc. with each injection till 1.0 cc. is reached. This dose is continued until a total of 10 cc. has been given. Even better results are said to follow intradermal injections of the toxoid beginning with dilutions of at least 0.1 per cent to avoid necrosis. It is usually possible to demonstrate in the recipients whose blood is originally low in antitoxin a rise of several times its original titer after the course of injections is finished. Possibly a *vaccine* should be given with the toxoid. Of all these preventive measures one may say that they are certainly not uniformly successful but that in some cases they seem to be effective in checking recurrences. In a *liar* where continuous remissions are so frequent conclusions are difficult to reach.

TREATMENT—The treatment of established local staphylococcal infections still rests chiefly upon the old principles of *rest, elevation, heat* and *drainage* when pus has formed. For

by rubbing staphylococci into the skin or by slight trauma such as pulling out a hair or by the presence of ingrown hairs. They may appear beneath adhesive plaster. They may at times be associated with lack of cleanliness. They are thought at times to appear in people because they are run down but they also appear frequently among athletes apparently in good training. Some of these factors are readily explained as local trauma or as interference with normal excretion from the skin but we can say little about the underlying individual or periodic variations in susceptibility among people except that they seem to exist even if no reliable method of measuring them has been found.

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increased the rate of survival. The combination of drug and antitoxin was still more effective. Farrell similarly found that in mice sulfapyridine alone did not alter the lethal effect of five average lethal doses of staphylococci but that when preceded by antitoxin it did protect the mice from death although abscesses of liver, spleen and kidneys developed. Bayliss found that the toxins were not neutralized by sulfanilamide, sulfathiazole or sulfapyridine. Osgood, working with staphylococci and alpha streptococci in cultures of living human marrow, found that *neoparsphenamine* in concentrations of 3 to 9 parts per million was far more bactericidal than sulfanilamide and sulfapyridine in concentrations of 1 to 10,000 and did not significantly damage the marrow cells. *Stamoxyl* still has its advocates. There are other substances such as *gramicidin* and *penicillin* which are bactericidal for gram positive organisms in extremely high dilutions and other substances which affect gram negative organisms as well. The value of these substances clinically is not yet proved.

The use of these bactericidal or bacteriostatic agents in combating staphylococcus bacteremia is not within the scope of this paper. The difficulty with their use in staphylococcal infections limited to the superficial tissues is the matter of getting them into contact with the organisms. Reaching the lesion by way of the blood stream they may well prevent bacteremia or even local extension and are to be used if the lesion seriously threatens either. Applied or injected locally, however, their use is limited by the presence of dead tissue once that has formed. No infected lesion can be expected to heal until the dead tissue has been extruded and conversely, once the dead tissue has been extruded, almost any superficial localized staphylococcal infection will quickly heal. The chief indication is therefore *to get rid of the dead tissue* which is usually best done by adequate drainage. A small opening of course may be adequate. Each lesion must be studied and treated according to its own peculiarities. The local use of bactericidal or bacteriostatic agents in the writer's experience sometimes seems a useful adjunct to drainage and

drainage potassium hydroxide in the form of the stick or the saturated solution cautiously applied with a toothpick swab is useful in getting rapidly through the skin without incision. The use of 95 per cent phenol to enlarge sinuses already made or even to open abscesses that are near the surface is still good practice. The injection of novocain slowly and carefully before incision is now more often used than is freezing. For carbuncles the persistence of the time tried methods of incision excision carbolization and radiotherapy tells that no one method is best in all instances.

Two new products employed in staphylococcal infections are *bacteriophage* and the sulfonamides. Meleney and Jern have used bacteriophage successfully in over a hundred cases of local staphylococcal infections by injecting the bacteriophage directly into the lesion repeatedly until cure is effected. The potency of the bacteriophage is maintained and tested in a special laboratory where stock is kept available. In their hands no serious untoward results have occurred and cures have taken place. There is difference of opinion on the purpose of the use of bacteriophage. Krueger and Scribner in a report adopted by the Council on Pharmacy and Chemistry say: "Altogether one gains the impression from the literature to date that staphylococcus phage preparations carefully prepared and intelligently used for systemic or local immunization in the conditions mentioned are useful therapeutic agents with about the same indications for clinical applications as staphylococcus vaccines and toxoid." Meleney and Jern recommend the bacteriophage where it can be placed in contact with the organisms in the tissues or blood stream which is quite different from the indications for use of vaccines or toxoid.

The sulfonamides have been subjected to experimental as well as clinical experience in treating staphylococcal infections. Brovning reports the recent literature and also experiments of his own in which mice treated with sulfanilamide survived staphylococcal infection hardly more often than did the untreated controls. Treatment with *M and B 693* monacetyldiaminodiphenyl sulfone or staphylococcus antitoxin

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sometimes not. Their use in prevention of infection in contaminated wounds and their systemic use in controlling bacteremia are now of recognized value.

INFECTIONS CAUSED BY STREPTOCOCCI

Much of the fear of superficial infections of streptococcal origin has been dispelled by the introduction of the sulfonamide drugs. Their extraordinary efficacy in combating such infections has been proved beyond question. This is especially true of the diffuse types of infection such as erysipelas, lymphangitis and lesions grouped under the term cellulitis. It is also true that certain strains of streptococci are more susceptible to sulfonamides than are others, the aerobic beta hemolytic varieties being in general the most susceptible. The standard drug for use in these infections is still *sulfanilamide*, given by mouth or parenterally, although it is quite probable that as experience with other sulfonamides accumulates one of them will take its place. The use of these drugs in no way lessens the surgeon's responsibility for searching for a focus of the infection, which is often found at the point of entry of the bacteria into the body. Drainage of an abscess or removal of a foreign body may often be necessary to effect a cure.

There are three clinical types of infections associated with streptococci that are worthy of special mention. The first is *hemolytic streptococcus gangrene*, as described by Meleney in 1914. The second is the group of infections associated with the so-called *microaerophilic hemolytic streptococci*, often found as chronic undermining ulcers, but occurring in other forms as well. The third is *synergistic gangrene*, which usually occurs in wounds involving abdominal or thoracic viscera.

HEMOLYTIC STREPTOCOCCUS GANGRENE—This condition is primarily an infection of subcutaneous tissue, the probable portal of entry being often a trivial wound of the skin. Liquefaction of a large area of subcutaneous tissue occurs, with secondary gangrene of some of the overlying skin. The gangrene of the skin begins as a small purplish patch which may become surmounted by a bulla, constituting the pathognomonic sign of the disease.

Treatment consists chiefly of wide incisions beyond the limits of the abscess. The writer has seen no case since the introduction of the sulfonamides but one would expect that they would be indicated as adjuvants to surgery.

INFECTIONS BY MICRO-AEROBIC HEMOLYTIC STREPTOCOCCI—The second group *ie* those associated with micro-aerophilic streptococci are usually chronic ulcerated lesions which undermine tissues to varying depths even at times penetrating bone. These organisms are characterized by an extraordinary capacity for invasion. Even in lesions that grossly seem to have wholly adequate drainage they will take advantage of microscopic foci as starting points from which to burrow into seemingly healthy tissues. We have seen the femoral artery lying beneath the granulating base of a fairly clean looking lesion invaded so as to lead to several nearly fatal hemorrhages and finally require resection of a portion of the artery.

Treatment—The great power of invasion possessed by these organisms makes it necessary to eradicate them even from well drained wounds and for this purpose *zinc peroxide dressings* have proved their value. It is essential to get the zinc peroxide into contact with the organisms over the entire surface of the lesion and therefore the first step in treatment must be the excision of overhanging skin edges and the opening of sinuses as far as the local anatomy permits. *Sulfanilamide* given by mouth may also assist in controlling the infection but in itself is usually not enough.

SYNERGISTIC GANGRENE—The third lesion known as synergistic gangrene has been shown by Meleney to be caused by a micro-aerophilic nonhemolytic streptococcus associated with hemolytic *Staphylococcus aureus*. The infection manifests itself as a painful tender red swelling of the whole or part of the wound. The pain and tenderness are the diagnostic features being far more intense than would be suggested by the appearance of the lesion. As the zone of redness and swelling spreads the center of the lesion becomes purplish and then ulcerates. From the tissues of the red zone the streptococcus can be cultivated from the central area the staphylococcus and contaminants. Animal experiments indicate that both the

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streptococci and the staphylococci must be present to produce the lesion

Treatment—Radical removal of the lesion excising the zone of redness as well as the gangrenous area is the treatment of choice followed preferably by zinc peroxide dressings

Therapeutic Methods in Staphylococcal Infection

In any infection associated with streptococci the main questions now are whether the sulfonamides will affect the organism which one to use and how to use it

Refractoriness of Certain Strains—Certain strains of streptococci have been found to be refractory to sulfanilamide Bliss, Long and Feinstein for example report that certain varieties of streptococci are refractory both in vitro and in vivo Spaulding and Bondi describe two weakly virulent strains of anaerobic group A hemolytic streptococci one of which appeared to be resistant to sulfanilamide in mice while the other was moderately susceptible After adaptation to aerobic incubation, both became refractory Strains of streptococci do appear at times to change their cultural requirements and their hemolytic properties and it is too soon yet to be dogmatic about the indications for the use or avoidance of sulfonamide therapy based on laboratory reports of the strains of streptococci recovered from a lesion

Choice of Drug—The question of which of the sulfonamides to use is still unsettled Sulfanilamide has probably been the drug most extensively studied and tried clinically It is recommended for infections caused by hemolytic streptococci on excellent authority There is reason to think however that sulfathiazole and sulfadiazine may be equally effective and less toxic especially in mixed infections

Local versus Systemic Use—It is impossible to state clearly at the present time what are the indications for the use of the sulfonamides locally systemically and by both routes together There are fragmentary bits of evidence however from which one may piece together a rational concept Where the organisms have spread beyond reach of local application of the drug the need for systemic dosage is obvious At the other extreme where the lesion is superficial and open so that

the drug can be brought grossly into contact with every part of its surface it seems to be proved that local application alone will get rid of hemolytic streptococci Colebrook and others⁹ who have studied this matter emphasize the advantage of preceding the application of the crystals of the drug by wet dressings for two or three days in order to get rid of crusts slough and exudate from the surface of the lesion Similarly the use of crystals on the surface of fresh wounds to prevent infection whether the wounds are later closed or not in selected cases is apparently becoming recognized to be good practice²

The chief controversy centers about the question of the effectiveness of sulfonamides used locally in *suppurating* wounds It is known that pus diminishes the effective action of sulfanilamide but clinically and in experimental animals² evidence can be brought to show that the action is not wholly inhibited Hawking's experiments are interesting in which he showed that sulfanilamide can penetrate dead tissue but that in living tissue no higher concentration can be obtained by local application than by oral administration This observation accords with a conception of the use of these drugs which may be broadly stated as follows where one is primarily interested in combating organisms that have invaded living tissues whether in the wall of an abscess or elsewhere systemic dosage is indicated but where the threat of invasion is not paramount local applications may do good and may even be preferable to systemic dosage The type of organism present in the lesion, the amount of pus and dead tissue present and the accessibility of the tissue surfaces of the lesion all play their part in determining the effectiveness of local application Often the combination of local and systemic dosage is indicated

GAS GANGRENE

This is the term given to certain severe infections in which gasforming anaerobic organisms invade the tissues usually spreading with great rapidity causing gangrene great toxemia and often death The commonest organism found is the A type of *Clostridium welchii* but the infection is often a mixed

one and other anaerobes may be present notably *Cl. septicum* and *Cl. novyi*. Streptococci and indeed almost any type of organism may also be present. It is worth stating that neither the presence of gas bubbles in the tissues nor the presence of *Cl. welchii* in the wound is diagnostic of gas gangrene. The entire clinical syndrome must be present as foundation for the diagnosis although as a practical matter when the diagnosis is suspected the finding of gas in the tissues or of organisms in a smear from the wound that resemble *Cl. welchii* may be sufficient confirmatory evidence to justify the treatment of the lesion as if it were gas gangrene.

DIAGNOSIS—The infection fortunately is an infrequent one and no surgeon sees many cases. Even of the war casualties among soldiers and civilians in England Mullaney says: "Infection with gas forming anaerobes is a common almost universal feature of all war wounds; gas gangrene is an infrequent complication of such infection." The diagnosis rests on several factors all of which may not be present in any case. First the likelihood of anaerobes having access to the lesion. It may develop around a colostomy opening as well as in grossly contaminated street wounds. Second the presence of poorly drained dead or damaged tissue especially muscle. Third the presence of diabetes or arteriosclerosis. Fourth the characteristic odor. Fifth rapid increase of pain and tension in a wound. Sixth evidence of toxemia as shown first by a sharp rise in the pulse rate and restlessness with later rise of temperature, vomiting and euphoria. Seventh increased swelling and tension in the wound area with evidence of gas in the tissues. X rays may early show the presence of gas in the tissues even before the clinical evidence of infection is convincing. In lesions in which gas gangrene is suspected or anticipated it may be advisable to take X ray films as often as several times a day in order to make an early diagnosis.

PREVENTION—The treatment of gas gangrene is the subject at present of much controversy. Certain procedures however are pretty generally accepted. In prevention it is clear that *debridement* of dirty or crushed wounds and the avoidance of locking up organisms in the tissues by suture are of primary importance. *Early diagnosis* is also clearly important because

no infection can spread with greater rapidity than gas gangrene. To increase the number of early diagnoses the hospital surgical personnel, interns and nurses should be taught to have the possibility of this infection ever in their minds and to recognize the early signs and symptoms, particularly the smell and finally to waste no time in getting treatment started.

TREATMENT—Open Drainage—The treatment that is most generally accepted is wide incisions into the affected tissue opening the skin, deep fascia and fascial sheaths of muscles freely to relieve tension and provide surfaces for drainage. As much dead muscle as possible is removed, avoiding injury to blood supply, and recalling that the main blood supply of muscles of the extremity is often located at the proximal end so that the distal portion of the muscle may have to be removed with the proximal even if the distal portion does not seem to be grossly infected.

The matters in treatment that are yet undecided have to do with the use of the sulfonamide drugs locally and systemically, the use of serum and the value of x-ray therapy.

Sulfonamides—Concerning the sulfonamides, experimental work has given conflicting evidence depending perhaps on how the experiments were done. In small animals it is difficult to set up conditions which approximate the lesions found in human beings. Hawking, for example, incised and traumatized the thigh muscles of guinea pigs, then applied 0.5 gm. of a sulfonamide to the lesion together with a cloth soaked in an emulsion of a culture of anaerobes. He then closed the wound. If the animal survived, he reopened the wound three days later, removed the cloth, reapplied the drug and again closed the wound. His conclusions were that the sulfonamides have a protective action against *Clostridium welchii* and *C. septicum* but not against *C. oedematiens*; that sulfathiazole is the most potent of the sulfonamides tested; that local application is better than systemic; and that delay in application of the drug lowers its efficacy rapidly. There were no survivors when the drug was given six hours after the organisms were introduced. Bliss, Long and Smith concluded that under the conditions of their experiments, sulfadiazine and sulfathiazole given locally afforded the best protection among the sulfon-

amides but their experiments were conducted under circumstances far removed from clinical conditions

Altogether the experimental work so far gives no clear notion of the value of the sulfonamides in treating gas gangrene infections as they occur in humans. Clinical reports also are at variance. It seems probable that benefit in some cases would result from the use of these drugs but just which drug and how to use it has not been determined. Sulfanilamide has been recommended although the experimental evidence suggests that some of the others may be better.

Zinc Peroxide—The use of zinc peroxide locally in cases of gas gangrene has seemed to give some evidence of the efficacy of this nonirritating oxidizing agent in this disease. In certain cases where it has been used after the debridement of grossly involved tissues there have been rapid marked clinical improvement and rapid disappearance of the organisms from the wounds. This substance should have more extensive trial.

Anti gas Gangrene Serum—The use of anti gas gangrene serum has fallen into disrepute recently based largely on the impressions of surgeons who have not felt that it influenced the course of the patients in whom they have tried it and also on the theoretical grounds that antisera against such a mixed and varied flora as may be found in gas gangrene infections would only occasionally be specific. This does not mean that serum has been given up and there is evidence experimentally that against some of the organisms especially *Clostridium oedematiens* it can be highly effective. Clinically however the value of serum has not been established.

Radiotherapy—The most outspoken advocate of radiotherapy in gas gangrene is J. F. Kelly. He is recently quoted by Meleney as having treated or collected 364 cases with a total mortality of 11.5 per cent. He has recommended (1) avoidance of amputation for gas gangrene per se (2) debridement (3) roentgen therapy consisting of about 100 roentgens per port using sufficient ports to include the infected area with suitable kilovoltage to give penetration and an aluminum filter of at least 1 mm. thickness. Two treatments daily should be given. He says: "If treated with x-ray according to direc-

tions no case dies of gas gangrene that has not sufficient reason for death from causes other than the gas gangrene^{25 2} Cantril³ goes even further in advising against any surgical procedures in the acute phase of the infection where x rays are available. Important details are lacking in Kelly's reports such as the proportion of his cases in which the diagnosis was proved, the severity and extent of the lesions and the nature of the therapy done other than x ray. Adverse reports have appeared about x ray treatment^{21 3} but in these too details are lacking. Experimental work by Caldwell and Cox²⁶ fails to show any benefit from x ray therapy in guinea pigs but this work is criticized because small laboratory animals are apt to withstand exposure to x rays poorly.

In summary one can say of the treatment of gas gangrene that preventive treatment of wounds, early diagnosis and prompt institution of free drainage are measures of established value. Concerning the value of the sulfonamides, zinc peroxide sera and roentgen therapy, uncertainty still exists. Further research and clinical trial are clearly indicated.

TETANUS

In the case of war wounds and of severe injuries in civil life such as compound fractures tetanus antitoxin of course is given. It is the minor injuries of skin and subcutaneous tissue which confront the surgeon daily which raise in his mind the doubt of whether to give antitoxin or withhold it. It is now no exaggeration to say that the development of tetanus toxoid constitutes one of the greatest boons that medicine has given to humanity, affording protection as it does against tetanus occurring in wounds large or small.

The preparation of tetanus toxoid was described by Ramon in 1925. It is now supplied by several pharmaceutical houses obtained from highly potent tetanus toxin which has been detoxified by the addition of formalin and then precipitated by aluminum potassium sulfate and resuspended in saline. It therefore contains no serum. A few severe reactions have been reported following its injection but they seem to be far less frequent than those following the injection of antitoxin. It was used to protect horses in France and became

anudes but their experiments were conducted under circumstances far removed from clinical conditions

Altogether the experimental work so far gives no clear notion of the value of the sulfonamides in treating gas gangrene infections as they occur in humans. Clinical reports also are at variance. It seems probable that benefit in some cases would result from the use of these drugs but just which drug and how to use it has not been determined. Sulfaril amide has been recommended although the experimental evidence suggests that some of the others may be better.

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widely used for men first in the French army and was later adopted by the British and American armed forces. Millions of injections have been given by this time and the harmlessness and effectiveness of the toxoid proved.

The toxoid is given in a series of injections subcutaneously each of 1 cc. The second injection follows the first usually by about eight weeks. The third is given a year later. About three to six months after the second injection the titer of antitoxin circulating in the blood of the recipient rises but more important is the fact that his capacity for the rapid production of antitoxin also is enhanced so that he responds to a subsequent stimulating dose of toxoid with an enormous production of antitoxin in the course of a few days. The degree of immunity so obtained is many times that supplied by the usual prophylactic dose of antitetanus serum. Once a person has been protected by the first two doses of toxoid and a six months interval has passed he may then be rendered almost absolutely immune to tetanus by the injection of another dose of toxoid which carries with it practically no risk of harm, no danger of serum reaction and only slight discomfort. The toxoid may be given to children together with diphtheria toxoid or may be given with typhoid vaccine. The length of time that its effect lasts after the third dose is not yet established but it is thought likely that an injection should be given every three or four years.

The purpose of the foregoing paragraph is to encourage the adoption of prophylactic injections of tetanus toxoid wherever possible—and there are few instances where it would be impossible or inadvisable. Although tetanus is an infrequent disease in civil life the danger of its development following injuries is often present. A major complication of superficial wounds can be eliminated if people so desire. For a description of the subject of tetanus and the treatment of the disease when established reference is given to the excellent article by Norman T. Kirk in *Nelson's Loose Leaf Surgery*.

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Ed.]

INFECTIONS OF THE CHEST

ROY O M CLURE M D F A C S †

WHEN infectious organisms invade the thoracic cavity the tissue reactions differ but little from those elsewhere in the body. The clinical course of the patient with intrathoracic infection depends on the progress of the infecting agent and varies from the minimal systemic response obtaining when the normal defensive mechanism of the body is successful to the rapidly fatal overwhelming septicemias.

It is however not with these two extremes that the surgeon is especially interested. More within his province are those cases in which a balance is struck between the invading organism and the patient's resistance to infection. Clinically this is the period that corresponds to localization of the infection and abscess formation. It is at this stage that timely surgical intervention may be successful in turning the balance in the patient's favor.

Recognition of intrathoracic abscess formation is often a matter of great difficulty, the more so when too much reliance is placed on clinical examination. The rigid thoracic cage which so well protects the contained viscera and spaces also renders them relatively inaccessible to ordinary clinical methods. The development of roentgenology has made possible the accurate localization of intrathoracic abscesses that is so essential to successful surgical approach.

This consideration of the surgical aspects of intrathoracic infection will be dealt with under four headings: Empyema, Lung Abscess, Mediastinitis and Pericarditis, and is offered as a group presentation. The sections on Empyema and Lung Abscess are contributions of Dr. Conrad Lam and Dr. Henry N. Harlins, while the sections on Mediastinitis and Pericar-

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quently found. The ratio of pneumococcal to streptococcal empyema will vary with the period being studied. For example in the Henry Ford Hospital series sixty four empyemas treated in the period 1916-1923 showed only thirteen of the pneumococcal type and thirty seven of the streptococcal type. Benson and Penberthy reported 144 children treated in the period 1936-1941. Cultures of the pleural fluid showed the pneumococcus to be present in 74 per cent, the streptococcus in 10.7 per cent, the staphylococcus in 6.7 per cent, no growth in 8 per cent and influenza in 0.9 per cent. These writers call attention to the decreased incidence of empyema and the lowered mortality in those cases which do develop empyema. In 1936 there were 697 cases of pneumonia in the Children's Hospital of Detroit with thirty five cases of empyema. The mortality for pneumonia was 9.7 per cent and for empyema 8.6 per cent. In 1940 there were 1174 cases of pneumonia with only sixteen cases of empyema. The mortality for pneumonia was 6.5 per cent and the empyema mortality was nil. The decrease in the mortality in pneumonia and the incidence of empyema is attributed to decreased virulence of the organism and the advent of the new sulfonamide chemotherapeutic agents.

TREATMENT

The successful treatment of empyema demands the application of surgical principles and judgment rather than the use of any one method of treatment in all cases. As emphasized by Van Hazel there are two main objectives: (1) to drain the pus and (2) to obliterate the cavity. If this can be accomplished by *needle aspiration* the requirements are satisfied but such cases must be rare. However many patients are cured by the almost nonsurgical procedure of *closed drainage* through the intercostal tube. Rib resection with *open drainage* is indicated in other instances. Allen stated: "There has been something of value in most of the methods of treatment advocated. The objectionable feature has been the feeling of some authors that their particular method should be applied to all types of empyema and carried through to a final conclusion."

ditis are largely due to the efforts of Dr. Lawrence Falls and Dr. George Wadsworth.

EMPHYEMA THORACIS

Pthog d T m t

CO RAD R LAM MD

Empyema is the commonest form of suppuration in the chest cavity with which the surgeon has to deal. It is rarely if ever a primary condition but is a complication of preëxisting disease. It is usually diagnosed by the internist who is caring for a case of pneumonia or sepsis.

Pthog ss

The origin of the inflammatory process in empyema seems to be simple. In pneumonia the pathologic change extends to the periphery of the lung where a more or less fibrinous exudate forms. This exudate is frequently infected with the pathogenic organism from the parenchyma of the lung. If the pneumococcus is the invading organism there is considerable fibrin formation the empyema is apt to be more localized and the pus is thicker. On the other hand the streptococcus produces less of a plastic exudate the lung is not adherent the pus is thin and the toxicity is usually greater.

Other modes of entry are metastasis from other foci of infection direct infection from perforation of the chest wall with bullets knives and other objects and perforation of the esophagus by instrumentation and foreign bodies. One hundred and sixty-eight patients with empyema at the Henry Ford Hospital had the following primary diseases: lobar pneumonia, bronchopneumonia, influenza, bronchopneumonia, lung abscess, coryza, nephritis, mastoiditis, erysipelas, subphrenic abscess, postabortal infection, typhoid fever, operation for diaphragmatic hernia, pneumococcus peritonitis, pulmonary infarct, perforation of esophagus, scleroderma, osteomyelitis of cervical vertebra and stab wound of thorax.

After an extensive review of the literature Ehler stated that about 80 per cent of empyema is caused by pneumonia. Hence it is reasonable to suppose that the pneumococcus, streptococcus and staphylococcus are the organisms most fre-

quently found. The ratio of pneumococcal to streptococcal empyema will vary with the period being studied. For example in the Henry Ford Hospital series sixty-four empyemas treated in the period 1916-1923 showed only thirteen of the pneumococcal type and thirty-seven of the streptococcal type. Benson and Penberthy reported 144 children treated in the period 1936-1941. Cultures of the pleural fluid showed the pneumococcus to be present in 74 per cent, the streptococcus in 10.7 per cent, the staphylococcus in 6 per cent, no growth in 8 per cent and influenza in 0.9 per cent. These writers call attention to the decreased incidence of empyema and the lowered mortality in those cases which do develop empyema. In 1936 there were 697 cases of pneumonia in the Children's Hospital of Detroit with thirty-five cases of empyema. The mortality for pneumonia was 9.7 per cent and for empyema 8.6 per cent. In 1940 there were 1174 cases of pneumonia with only sixteen cases of empyema. The mortality for pneumonia was 6.5 per cent and the empyema mortality was nil. The decrease in the mortality in pneumonia and the incidence of empyema is attributed to decreased virulence of the organism and the advent of the new sulfonamide chemotherapeutic agents.

Treatment

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The literature contains reports of cases treated by different methods giving comparative mortality figures. One must guard against drawing unwarranted conclusion from these statistics. Because a large series shows a greater mortality in cases treated with the intercostal tube does not mean that this method should be discarded. It may mean that this author used the intercostal tube only in his desperately ill patients. For example, Eliason and Pfeiffer³ reported 140 cases treated surgically with a total mortality rate of 4 per cent. The lowest mortality was in instances in which the closed method was followed by the open method (9.09 per cent) and the highest was when the closed treatment alone was used (46.1 per cent). Hochberg⁴ studied 288 cases of acute empyema classifying them as complicated and uncomplicated. A comparison of the mortality under various forms of treatment is given in the accompanying tabulation.

TABULATION

CASE MORTALITY IN 288 CASES OF ACUTE EMPYEMA TREATED BY DIFFERENT METHODS (Hochberg)

Type of Empyema and Method of Treatment	Total Cases	Complicated Cases		Uncomplicated Cases	
		Number	Deaths	Number	Deaths
Simple Empyema					
Aspirated	31	31	24		
Closed method	3	3	7	27	5
Rib resection	61	15	6	43	
Complicated Empyema					
Aspirated	4	16	1	9	3
Closed method	9		1		2
Rib resection	108	21	9	87	1

It is beyond the scope of this article to discuss details of operative technique and management. From time to time there are new suggestions for the irrigation of the cavity through the intercostal tube. The author has continued to use a simple Y tube arrangement whereby the cavity can be filled

and emptied intermittently a negative pressure being maintained by siphonage in the intervals between irrigations. Saline solution and Dakin's solution are commonly used as the irrigating fluid. Adams⁹ at the Lahey Clinic has used sulfanilamide solution (0.8 per cent) and believes it is of value for local use. In this connection it is interesting to note such isolated reports as that of Small and Greenberg¹⁰ who treated a case of chronic streptococcal empyema by repeated aspirations and injections of neoprontosol.

Since the successful treatment of empyema consists in the application of surgical principles to individual cases rather than the use of any one method of treatment it is felt that the important points in treatment may be emphasized best by outlining the procedure in three typical cases.

CASE I. PNEUMOCOCCAL EMPYEMA IN CHILD TREATED SUCCESSFULLY BY CLOSED INTERCOSTAL DRAINAGE.—J. M. was a white girl aged seven years. She was admitted to the hospital on December 1, 1940, after having been sick for one month. About October 25 she had an upper respiratory infection. Intestinal flu was diagnosed on November 7. The following day the left lower lobe pneumonia four days later and she was given 40 grains of sulfanilamide daily. Physical findings of empyema were noted on November 16 and at this time 100 cc of greenish fluid was removed from the left pleural cavity. Small taps were carried out on November 22 and 29. At this time she was very ill, pyrexia was marked and she had frequent spasms of coughing, dyspnea and cyanosis.

On the day of admission the white blood cell count was 37,500, 90 per cent being polymorphonuclears. The temperature was 103.2 F, pulse 146, and respiratory rate 66. Roentgen examination of the chest showed the left side to be completely opaque with marked mediastinal shift to the right (Fig. 100). Two hundred cc of thick greenish pus was removed and the pneumonia culture was recorded on culture. The next day another 100 cc of pus was removed and the fluid was drained off in 100 cc of Dakin's solution as a leguminal disinfectant. Cultures were not made. Immediately thereafter the patient was given sulfadiazine 100 mg five times daily. On December 16 the empyema cavity measured only 5 cc and the postero-anterior roentgenogram

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TABULATION

C M T 288 C F T TED V
M m (Hochberg)

Type of Empyema Method of Treatment	Total Cases	Complicated Cases		Uncomplicated Cases	
		No. mbs	Deaths	No. mbs	Deaths
Simple or Loc. pyem	31	31	24		
Aspirated					
Closed	3	8	7	27	5
Open					
Tube	61	15	6	43	2
Aspirated					
Closed	24	16	1	8	3
Open					
Tube	29	2	1	2	
Aspirated					
Closed	108	21	9	8	1
Open					
Tube					

It is beyond the scope of this article to discuss details of operative technique and management. From time to time there are new suggestions for the irrigation of the cavity through the intercostal tube. The author has continued to use a simple Y tube arrangement whereby the cavity can be filled

F 103



F g 104



F g 105

F g 106

F g 103 (C II) -W II loc I I p
 F g 104 (C II) -L al g g m
 F g 105 (C II) -I l f tw k f p d nag Th
 l d h h p d b l pl l h k f ll
 g l f
 F g 106 (Ca II) A I p f l l f h los g f
 f dra g

showed satisfactory evacuation of the p's and correction of the mediastinal shift (Fig. 101). Ten days later the intercostal tube



Fig. 100 (Case 11)—Mediastinal shift corrected after removal of pleural effusion.



Fig. 101

Fig. 102

Fig. 101 (Case 11)—Residual pleural effusion after removal of intercostal tube. Fig. 102 (Case 11)—Fifteen days later, after removal of pleural effusion, the mediastinal shift has corrected.

as evidenced by the fact that the patient was discharged. The final report was on June 6, 1941, re: final complete resolution of the process (Fig. 102).

ten and a rim negative rod which was not identified. On April 11 an intercostal tube was inserted. The temperature was 104° F on this day and four days later was normal. The pressure roentgenogram on April 15 showed satisfactorily clearing of the chest fluid (Fig. 106). The patient was discharged on May 16.



Fig. 107

Fig. 108

Fig. 107 (C III) - M d b f f ght pl l
 Fig. 108 (C III) - R l f l k f d g h l

th a small piece of the t l t l l plate t l l as removed on May 24 and a v k l t l e s u s as closed and h as released t work.

Comment—Cases I and II were both pneumococcal infection but the first was an empyema involving the entire pleural cavity with mediastinal shift and although the pus was thick drainage was easily accomplished by intercostal catheter drainage. The second case showed a different picture the empyema was obviously well localized and the mediastinal structures were not pushed to the opposite side. Wide open dependent drainage seemed indicated and resulted in speedy healing. The intercostal tube seemed advantageous in the third case because of the diffuse nature of the empyema and its putrid character. With a closed system being used there was never any odor about the patient while he was being cared for.

CASE II PNEUMOCOCCAL EMPIYEMA IN ADULT TREATED BY RIB RESECTION AND OPEN DRAINAGE—W. M. was a white male aged fifty-two years. He was admitted on March 31, 1941. Five days before admission he had a severe chill and since had had fever and sweats daily. Physical examination showed impairment at the right base and the clinical diagnosis of lobar pneumonia was made. The sputum showed Type II pneumococcus. The white blood cell count was 10,500. Treatment with sulfathiazole and serum was begun.

On April 3 a thoracentesis was done with the removal of a few cubic centimeters of straw-colored fluid which yielded Type II pneumococcus in culture. There was a daily temperature variation to 100° F. Purulent fluid was removed from the lower right chest on April 9 and films of the sediment on the following day showed encapsulated fluid living pneumococci; the lower half of the right chest (Figs 103-104). On April 11 a portion of the eighth rib was resected in the region of the posterior axillary line. A large rib-drain tube was inserted and a moderate quantity of thick pus and fibrin was removed. Figure 105 shows the amount of plural retraction at the end of six weeks of drainage. The tube was removed in May and the patient discharged from the hospital on May 10. A week later the sinus was closed and the progress of the drainage shown further retraction. (Fig. 106)

CASE III MIN A MEN IC I ECTION IN ADULT TREATED BY
CLOS D INT EX TAT DRAT VE—The third patient is a white
male, age 40, who has been ill for 3 months. He was admitted on April 3, 1941.
There was a history of loss of weight and weakness, characterized by
prostration, fatigue, and anorexia. He was in bed for 3
days early in the illness. There was pain in the chest for three
weeks. At the time of admission the temperature was 103.4 F,
pulse 104 and respiratory rate 24. There was a flatness to percussion
over the right base. The hemoglobin was 10.000
with 76 per cent polychromasia. The leukocytes were 12,000.
Reported. The chest x-ray showed consolidation in the right chest.
Some of the lesions were calcified. The right diaphragm
partially obscured by consolidation of pleural space.
There was a small pleural effusion. The patient had
presented with a fever and weight loss. The patient had
lost 10 pounds (F 10).

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smell n fl l C h r f th fl l g gr p t l r d
rl h m l t c cr z o h d l r d

is continued or operative interference is decided upon. In certain cases however we believe that early interference is advisable. It is highly desirable to be able to operate early in those instances in which operation will have to be performed anyway. Delay in operation then is to enable a proper choice of cases to be made rather than to allow the abscesses to ripen and become more ready for surgical drainage.

In this regard we are largely in accord with the views of Neuhof and Touroff (1938). These authors studied forty five consecutive operative cases of acute putrid pulmonary abscess. Operation was considered imperative in cases of perforated abscess of which there were eleven as well as in a number of cases without perforation. These authors conclude that their operative indications for drainage of acute abscess have been valid. The following history exemplifies a successful drainage of acute abscess in which the operative indications might be considered as imperative by Neuhof and Touroff's criteria.

Cas 1—A white male aged fifty five years previously had an unresolved Type II pneumonia near the left margin of the heart as shown in Fig 109 which represents a film taken in March 1938. No new films were taken until his second illness three years later and he was in perfect health and able to work during this interval. On February 1, 1941 he had an acute chill which was followed by general malaise, burning fever, cough and anorexia. On admission February 5, 1941 his temperature was 104° F, the white blood count was 4000 with a marked shift to the left and the sputum showed Type III pneumococci. Subsequent roentgenograms are shown in Figs 110, 111 and 112.

During the subsequent two and one half weeks the patient's temperature fluctuated between normal and 104° F. Sputum was not so excessive as in many instances of lung abscess but it was not negligible.

Operation—Operation was performed on February 2, 1941, seventeen days after admission. Careful observation of the x-rays revealed that the best place to open the chest was by resecting a portion of the fourth and fifth ribs between the scapula and the spine. This was therefore done under local anesthesia and about 8 cm of the ribs was removed. The intervening intercostal muscle and the innermost part of the pleura below the fourth rib were

Co l s s

Although the empyema problem is not as great as it once was the mortality is still too high. It is probable that this will be reduced by the closer application of surgical principles to the treatment of individual cases and the utilization of the several new chemotherapeutic agents when they are indicated.

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ABSCESS OF THE LUNG

H N N H N M O F C S

Abscess of the lung is so protean in its manifestations that any advice concerning its treatment must be carefully weighed before being applied to any particular case.

At the Henry Ford Hospital we are conservative in applying *surgical drainage* to acute lung abscesses. We believe that a thorough trial of medical management including postural drainage, bronchoscopic drainage and neoarsphenamine injections should be made first. Then depending on the trend of developments and response to therapy the medical regimen

diameter but because of the presence of the bronchopleural fistula the exact capacity was not ascertained.

A diagnosis of empyema was made although it may well have been an encapsulated intralobar empyema. The fibrin was so attached that we could not scoop much of it away. A culture was made and a portion of the fibrin was taken for pathological examination. Two large rubber tire drains were inserted and a selene gauze spread around the edge. The patient left the operating room in good condition.

Postoperative Course—The postoperative course was uneventful. The size of the cavity was not measured because of the bronchopleural fistula. The patient left the hospital three months later and has now been at work for five months. He is entirely fever free, has gained about 20 pounds in weight and despite the presence of a small cavity with a patent bronchopleural fistula is entirely well. The cavity is still drained by a small tube. Eventually a muscle graft or operation to close the opening may be made.

Comment—5 mm y

While the possibility arises that this case may represent an acute exacerbation of a chronic abscess, there is no positive evidence of this. The chief lesson to be learned is that under certain circumstances prompt drainage of a lung abscess may be advisable.

Lung abscess most commonly follows pneumonia, impaction of foreign bodies in the respiratory tract and operation especially tonsillectomy. The bacteriology includes a multiplicity of symbiotic organisms. In early cases following pneumonia the pneumococcus may temporarily predominate but later fusiform bacilli, spirochetes and other bacteria are present. Treatment includes attempts to effect a cure by medical measures including drainage and bronchoscopic aspiration. In many cases surgical drainage is necessary. Such drainage should be performed as early as possible after medical measures have been given a fair trial.

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doubly incised and removed. The incision was close to and adherent to the chest wall and was opened into at its lowest point. It contained huge clots of fibrin pus and foul smelling air and

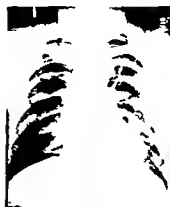


Fig 109

F 109-R 1

Fig 110-T 1



F 110

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f 11 es



Fig 111

F 111-T 1

Fig 112-T 1



Fig 112

k f

so t dra g

a br nch pleu r l fi tu l pres nt Th pat t c gh d p
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d meter but because of the presence of the bronchopleural fistula the exact capacity was not ascertained.

A diagnosis of a *acute abscess* was made although it may well have been an encapsulated intralobar pneumonia. The fibrin was so attached that we could not strip much of it away. A culture was made and portions of the fibrin were taken for pathological examination. Two large rubber tube drains were inserted and vaseline gauze spread around the edges. The patient left the operating room in good condition.

Postoperative Course—The postoperative course was uneventful. The size of the cavity was not measured because of the bronchopleural fistula. The patient left the hospital three months later and has now been at work for five months. He is entirely fever free, has gained about 10 pounds in weight and despite the presence of a small cavity with a patent bronchopleural fistula is entirely well. The cavity is still drained by a small tube. Eventually a muscle or skin operation to close the opening may be made.

Comment and Summary

While the possibility arises that this case may represent an acute exacerbation of a chronic abscess there is no positive evidence of this. The chief lesson to be learned is that under certain circumstances *prompt drainage* of a lung abscess may be advisable.

Lung abscess most commonly follows pneumonia, impaction of foreign bodies in the respiratory tract and operation especially tonsillectomy. The bacteriology includes a multiplicity of symbiotic organisms. In early cases following pneumonia the pneumococcus may temporarily predominate but later fusiform bacilli, spirochetes and other bacteria are present. Treatment includes attempts to effect a cure by medical measures including drainage and bronchoscopic aspiration. In many cases surgical drainage is necessary. Such drainage should be performed as early as possible after medical measures have been given a fair trial.

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INFECTIONS OF THE MEDIASTINUM

LAWRENCE S. FALLS, M.D.

ANATOMY—The mediastinum which is the region lying between the two pleural sacs is more a potential than a true cavity. It is occupied by lymph nodes and loose areolar tissue both of which provide excellent soil for the propagation and spread of infection. The space is arbitrarily divided into two parts by an imaginary plane passing from the sternal angle anteriorly to the lower border of the fourth dorsal vertebra posteriorly at the level of the tracheal bifurcation. The upper part known as the *superior mediastinum* contains the aortic arch and its branches, the superior vena cava and the innominate veins and through it pass the trachea, the esophagus, the thoracic duct and both phrenic and vagus nerves. The lower part of the space is subdivided by the pericardial sac into three portions known as the *anterior mediastinum*, the *middle mediastinum* and the *posterior mediastinum*.

The anterior mediastinum lying between the pericardium and sternum is the only part not containing important structures. This space is of little importance to the surgeon since it has no connections with the fascial space of the neck. Acute infections occurring here are secondary to osteomyelitis of the sternum or perforating wounds of the anterior chest wall.

The middle mediastinum is filled by the heart and pericardium. The posterior mediastinum occupies the space between the pericardium and the vertebral column and contains the thoracic duct, azygous veins, esophagus, aorta, vena cava and the vagus and sympathetic nerves.

The superior and posterior mediastina are important clinically since the spaces are directly connected by fascial planes with the viscero-vascular and prevertebral compartments of the neck. For clinical purposes it is convenient to consider infections of the superior mediastinum as examples of anterior mediastinitis since anterior drainage is possible while infections below the bifurcation of the trachea are truly posterior since collections may be drained only by posterior mediastinotomy.

PATHOLOGY—Mediastinal infections consist of lymphadenitis which may be acute, chronic or suppurative and phleg-

monous mediastinitis which may be localized diffuse or abscess formations

Acute infections of the mediastinum appear either as an adenitis involving the lymph nodes or as a diffuse phlegmon invading the cellular tissue. Acute lymphadenitis usually follows acute infection of the mouth and pharynx by direct extension through the lymphatics of the retropharyngeal space. *Streptococcus hemolyticus* is a common infecting organism.

Diffuse infection of the cellular tissue or *diffuse phlegmonous mediastinitis* can occur in a similar manner but more commonly follows perforation of the esophagus by a foreign body such as a fish or chicken bone or by instruments.

CASE I. MEDIASTINITIS FOLLOWING DILATATION OF AN ESOPHAGEAL STRICTURE.—This thirty-seven year old white female was admitted to the hospital on October 7, 1919. Three weeks earlier she had drunk about 1 pint of a mixture of hydrocyanic acid mixer and potassium permanganate. She was taken immediately to a nearby hospital where gastric lavage was done.

On admission the patient was very dehydrated and emaciated. She stated that she was able to take soft foods for a week following the accident but since then had been existing on liquids with resultant loss of 15 pounds in weight. After ten days of restorative treatment dilatation of the stricture which was at the level of the cricoid cartilage was begun and was repeated six times at five day intervals. Following the seventh dilatation the patient developed subternal pain. The temperature, pulse and white blood count rose gradually and altered physical signs appeared in the chest. Nine days later the patient died and an autopsy showed scarred and stenosis of the esophagus at the level of the cricoid with an ulceration through the wall 5 cm. in length. A large mediastinal abscess was present and the opened the pleural cavity to the right pleural cavity.

The breaking down of carcinomas of the esophagus, trachea or main bronchus has also resulted in infection of the mediastinum. Infection in the retroperitoneal space secondary to peritonitis may spread upward and involve the posterior mediastinum. Lung abscess, purulent bronchopneumonia and osteomyelitis of the ribs, sternum and vertebrae are rare etiologic factors in the development of mediastinitis. Metastatic infec-

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PATHOLOGY—Mediastinal infections consist of *lymphadenitis* which may be acute, chronic or suppurative and *phleg-*

dosage to keep the blood level between 10 mg and 15 mg per 100 cc are all indicated. Intravenous *neotarsphenamine* should be added in cases secondary to esophageal perforation to combat infection from the flora of the mouth.

Surgical drainage should be undertaken immediately in all cases of esophageal injury without waiting for the development of evidence of neck or mediastinal involvement. In other words operation is indicated even though the patient should be symptom free. Prompt exposure of the site of injury in the esophagus prevents spread of infection by promoting free drainage. Lesions above the bifurcation of the trachea i.e. above the level of the fourth dorsal vertebra are accessible to an anterior approach while lesions below the level are accessible only by posterior mediastinotomy except the rare cases of anatomical anterior mediastinitis.

Anterior mediastinotomy is performed through an incision along the anterior border of the lower third of the sternomastoid muscle. The strap muscles are retracted medially and the sternomastoid is pulled laterally. The thyroid gland is dislocated inward after ligating the lateral veins of Nocher and the carotid sheath and contents are displaced outward to permit entrance to the retrovisceral space.

Posterior mediastinotomy is a much more formidable procedure for it involves resection of paravertebral segments of two or three ribs after exact localization of the abscess. Great care must be exercised to avoid entering the pleural cavity though this is often difficult to achieve except by a two stage operation.

Symptoms

1 The study of mediastinitis is simplified if the older anatomic divisions are abandoned and the region is divided into anterior and posterior compartments on the basis of surgical approach.

The role of traumatic perforation of the esophagus in the etiology of acute mediastinitis is illustrated by a typical case report.

3 The value of prompt surgical intervention in traumatic perforation of the esophagus is stressed.

tion from a distant focus has been recorded. Fully three fourths of all examples of acute mediastinitis follow infections of the pharynx and perforations of the esophagus.

CLINICAL FEATURES—Only fulminating cases of acute mediastinitis present the classical signs and symptoms of *overwhelming toxemia* with recurrent chills and fever. In severe and moderately severe cases *dysphagia* and *dyspnea* are the outstanding symptoms. Other signs of mediastinal infection are *pain* in the chest, *tenderness* on percussion of the spine and *swelling* in the neck. Cyanosis and other signs of interference with circulation are rare except when the anatomical anterior mediastinum is involved. Pneumonitis, pleuritis and emphysema may be the only diagnostic evidence of mediastinitis in obscure cases especially when there is no obvious source of origin.

On *x-ray examination* widening of the mediastinum is valuable evidence in suspected cases. Abscesses produce globular shadow and occasionally a fluid level. Subcutaneous emphysema following esophageal injury is presumptive evidence of mediastinal infection. Collections in the retrovisceral compartment tend to push the trachea forward rather than to cause lateral deviation.

DIAGNOSIS—The diagnosis of mediastinitis depends largely on an antecedent history of the existence of conditions which might be followed by infection of the mediastinum. Traumatic perforation of the esophagus and infection of the fascial spaces of the neck are etiologic factors in fully 75 per cent of mediastinal infections. Positive physical signs may be wanting but tenderness in the neck or over the spine depending on the location of the infection can usually be elicited. Dysphagia and dyspnea are fairly constant signs. X-ray signs of mediastinal widening or displacement of the trachea provide valuable confirmatory evidence.

Treatment

Infection of the mediastinum should be treated as infections elsewhere. The comparatively ill patient requires prompt and energetic treatment. *Blood transfusion* repeated daily, *maintenance of fluid balance* and *stimulation* are sufficient

SYMPTOMS—Since pericarditis is secondary to disease process elsewhere in most instances the symptoms will be more or less masked by those of the primary disease. The chief symptoms are those of *sepsis* with cardiac embarrassment and *dyspnea*. The pulse is thready, the pulse pressure low. The area of cardiac dullness is increased. The heart sounds may be either diminished or increased depending on the position of the heart and relation to the effusion. A friction rub may be present.

DIAGNOSIS—The diagnosis of pericarditis can be made if the clinician is alert in the conditions which may produce it. The *roentgenogram* is of great value if the effusion is large. The physical findings are not constant. However in the course of pneumonia, empyema or other conditions commonly associated with pericarditis frequent examinations of the heart and roentgenograms will usually make the diagnosis possible.

Treatment

Surgical drainage of the pericardium should be carried out promptly. Drainage may be effected through the costal cartilages on either side of the sternum or through the sternum itself. From one to three costal cartilages may be removed, preferably the fifth and sixth on the left. Saline irrigation of the pericardium may be carried out postoperatively.

In ninety-nine cases reported by Shipley and Winslow in which open drainage was carried out, forty-nine patients recovered, forty-six died and the outcome was not mentioned in four instances. Truesdale collected 152 cases in which drainage was followed by recovery in 58 per cent.

The *sulfonamide drugs* may prove to be of great value in the treatment of pericarditis and should be used in most cases. The sulfonamide selected should depend on the organism cultured as in the treatment of other infections. Sulfanilamide is indicated in hemolytic streptococcus infection, sulfapyridine in pneumococcal infection and sulfathiazole in the staphylococcal infections.

Active supportive measures such as blood transfusion, parenteral fluids and oxygen will be necessary in most cases.

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ACUTE SUPPURATIVE PERICARDITIS

G. H. WATSON, M.D.

Acute suppurative pericarditis is an acute inflammation of the pericardium during the course of which a purulent exudate collects within the pericardial cavity.

ETIOLOGY—Pericarditis is probably never a primary disease. The most frequent source of the infection is pneumonia or empyema. Many cases are seen which result from metastatic infection from distant sites as in osteomyelitis, tonsillitis and abscesses in various locations. A few instances result from gunshot and knife wound of the pericardium.

The organisms most commonly cultured from the exudate are the pneumococcus, staphylococcus and streptococcus. Other organisms such as the influenza bacillus and various gram negative bacilli are seen but rarely.

MORBID ANATOMY—In pericarditis the exudate varies from a few drams to two liters. The exudate in a large number of cases accumulates behind the heart pressing it firmly against the anterior chest wall. For this reason diagnostic puncture may be hazardous.

The embarrassment to heart action depends on the mass of intrapericardial pressure and the rapidity with which this develops. The effusion exerts pressure both on the thin-walled auricles and the vessels at the base of the heart, particularly the superior vena cava.

SYMPTOMS—Since pericarditis is secondary to disease process elsewhere in most instances the symptoms will be more or less masked by those of the primary disease. The chief symptoms are those of *sepsis* with cardiac embarrassment and *dyspnea*. The pulse is thready, the pulse pressure low. The area of cardiac dullness is increased. The heart sounds may be either diminished or increased depending on the position of the heart and relation to the effusion. A friction rub may be present.

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Active supportive measures such as blood transfusion, parenteral fluids and oxygen will be necessary in most cases.

Case Reports

CASE I ACUTE SUPPURATIVE PERICARDITIS IN A 12 YEAR OLD BOY
TREATMENT BY SURGICAL DRAINAGE—This patient a twelve year old boy was hospitalized on April 30, 1941. For two and one half weeks before admission to the hospital he had been confined to bed at home with cough and high fever. His family physician had diagnosed pneumonia and had treated the boy with one of the sulfonamide drugs. He had been convalescing satisfactorily when, on April 4, he complained of pain in the shoulder was dyspneic and very apprehensive. A diagnosis of purulent pericarditis was made and a pericardial tap was done.

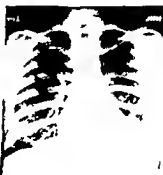


Fig. 113

Fg 114

F g 113 (Ca 1) — F l g d h r r p p r a p e n d u s f l
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to is f r t v e n t y f o u r h u t b u t t h e p u r t n f t h t p e r i d
they r e t u r n d t h e d i t l p r e o t h f l l p l p r e s
s u r e a d a n o t h t p v l d d 1000 c c o f p s H a s t h e
f e r r e d t o t h e h p t l f t r g e l d r n e

On examination of the hip in the patient, the 11-year-old boy of twelve height appeared relatively healthy. The patient was 103 cm tall, the blood pressure was 110/70 mm Hg, and the weight was 15 kg. The patient had no other symptoms.

h U rsn g f J D J h Al t d D C m ll gh f
se h se ascs

clest. The heart sound were very muffled and there was no friction rub. The heart was greatly enlarged and by x-ray showed the typical water bottle shape (See Fig. 113). No apical impulse was palpable. The neck veins were dilated, the venous pressure elevated to 150-160 mm of saline. The liver was enlarged a hand's breadth below the costal margin but was not tender. Pericardial tap done the day following admission yielded 45 cc of pale cloudy fluid. Culture showed anhemolytic streptococcus.

Three days after admission open drainage was carried out. Under local anesthesia an incision was made along the left border of the sternum and the fifth costal cartilage was resected. The pericardium was opened and sutured to the muscle fascia. Two cigarette drains with the gauze removed were placed, one to the posterior recess and one toward the apex, and these drained pus profusely postoperatively. The postoperative course was stormy. Flood transfusions, oxygen and sulfathiazole were used. Irrigation of the pericardium was carried out daily. On July 1 catheter drainage of empyema in the left chest was done. The patient's condition improved following this. Drains were removed from the pericardium three months postoperatively and the sinus tracts healed rapidly. The patient was discharged on August 24, 1941. Figure 114 shows the heart shadow after subsidence of the pericarditis.

CASE II. ACUTE SUPPURATIVE PERICARDITIS COMPLICATING OSTEO MYELITIS OF FEMUR. REPEATED ASPIRATIONS AND SULFATHIAZOLE THERAPY.—The ten-year-old boy was hospitalized on March 1, 1941. Four days before admission he had had an acute onset of pain in the right thigh with fever. On admission temperature was 102.4 F, the thigh red and swollen. A diagnosis of osteomyelitis of the right femur was made and sulfathiazole was started immediately. On March 4 surgical drainage of the right femur was done. On the same day a lateral pericardial puncture was made and x-ray films revealed enlargement of the heart shadow (Fig. 115). A diagnosis of suppurative pericarditis was made and aspiration yielded pus from which *Staphylococcus aureus* was cultured.

The pericardial sac was aspirated repeatedly following this and sufficient drainage was maintained. The sulfathiazole level of the blood during the acute stage was kept between 3 and 5 mg per 100 cc. On April 1 the level of the sulfathiazole in the pericardial fluid was 3 mg per 100 cc. On April 11 the

pericarditis had subsided. Sulfathiazole was continued until May. The osteomyelitis persisted until a septic arthritis had been produced in the right hip and then slowly subsided. The patient was discharged on November 13, 1941. Figure 116 shows the roentgen appearance after removal of the pericarditis.



Fig. 115



Fig. 116

Fig. 115 (Case II) - Frontal view of the chest showing consolidation of the right lower lung field. Fig. 116 (Case II) - Frontal view of the chest showing resolution of the consolidation after treatment.

5 mm. by

Acute suppurative pericarditis may be diagnosed more frequently if the clinician is alert. It is important that it be diagnosed since without proper management the outlook is hopeless. The treatment is surgical with drainage of the pericardial sac at the earliest possible time. The mortality is approximately 50 per cent with surgical drainage. The sulfonamide drugs give promise of being effective in this condition. A case treated with sulfathiazole and repeated aspirations is reported as well as one in which surgical drainage was alone.

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SURGICAL INFECTIONS OF THE PERITONEUM

WILLIAM A. ALTEMEIER M.D.†

INFECTIONS of the peritoneum still represent a problem of the first magnitude in general surgery and the large number of papers published each year on this subject indicates the widespread interest in this unsolved problem. Although the pathology and clinical pictures are well recognized the varied etiology, physiology and chemistry are bewildering and little understood. There is probably no other condition in general surgery whose successful management so commonly taxes the diagnostic ability, judgment, knowledge, operative technique and resourcefulness of the surgeon.

ETIOLOGY

All inflammations of the peritoneum have been classed as peritonitis. *Aseptic peritonitis* occurs after external mechanical violence or internal trauma by chemical antiseptics and extravasations of bile, urine, blood, pancreatic secretions or contents of ruptured cysts. *Septic peritonitis* has a bacterial etiology and clinically is of the greatest surgical import. In this paper only septic peritonitis will be discussed. Sixty-two years ago Grawitz pointed out that there are two main types of septic peritonitis: a *primary type* which apparently arises as a disease entity itself, being relatively rare and not dependent upon preceding intra-abdominal disease; and a *secondary type* which is commonly seen complicating the various lesions of the intra-abdominal organs or tissues.

PRIMARY TYPE—The primary type has a monomicrobial etiology, being caused by pneumococcus or hemolytic streptococcus. The route of spread is rarely demonstrable and it is often not definitely known whether these organisms reach

F	m	h	D	p	rm	f	S	g	ry	f	h	U	rs	ty	f	C		
Coll	g	f	M	d		d	h	G		u	G	ral	Hosp	l				
†	I	ru	ct		S	g	ry	U	rs	ty	f	G		Coll	g	f	M	d
C			O															

per carlit h d sub sided Sulfathazole as continued until May 1. The osteomyelitis progressed until a septic arthritis had been produced in the right hip and then slowly subsided. The patient was discharged on November 13, 1941. Four months later the roentgen appearance after ulcers of pericarditis.



Fig. 115

Fig. 116

Fig. 115 (Case II)—End stage of heart shadow, pericarditis complicated by osteomyelitis.

Fig. 116 (Case II)—Subsiding of the pericarditis following aspiration of the pericardial sac and treatment of the osteomyelitis.

5 mm. by

Acute suppurative pericarditis can be diagnosed more frequently if the clinician is alert. It is important that it be diagnosed since without proper management the outlook is hopeless. The treatment is surgical with drainage of the pericardial sac at the earliest possible time. The mortality is approximately 50 per cent with surgical drainage. The sulfonamide drugs give promise of being effective in this condition. A case treated with sulfathiazole and repeated aspirations is reported as well as one in which surgical drainage was done.

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the peritoneal cavity through the blood stream mediastinal and retropleural lymphatics intact intestinal wall retroperitoneal lymph nodes or the fallopian tubes

SECONDARY TYPE—The secondary type is usually a polymicrobial disease and the bacteria enter the peritoneal cavity commonly through a perforation or a compromised wall of an intra abdominal viscus. The most important sources of this kind of peritonitis are inflammations and injuries of the gastrointestinal tract and the most common single factor in its production is acute inflammation of the appendix. Other common gastric intestinal causes are perforation of a peptic ulcer perforation of the gallbladder perforation of intestinal ulcer such as tuberculous or typhoid traumatic perforation of the intestine acute pancreatitis acute diverticulitis areas of necrosis due to volvulus strangulation or intussusception of the bowel and occasionally sloughing of a malignant tumor.

Another frequent source of secondary peritonitis is disease or injury of the female genital tract. Septic abortion puerperal sepsis gonorrheal salpingitis trauma during parturition curettage or induced abortion and occasionally spontaneous rupture of tubo ovarian abscess are sources of peritonitis secondary to lesions of the female genital tract.

In the male injuries or suppurating lesions of the prostate and seminal vesicles occasionally produce peritonitis. Lesions of the urinary tract including injuries or purulent infections of the kidney are less important causes of secondary peritonitis.

Other important types of secondary peritonitis are postoperative infection caused by operative contamination of the peritoneum sponges or foreign bodies left in the peritoneal cavity leakage all over the suture line of an anastomosis continuation or spread of peritonitis for which the operation was originally done and tuberculous infection. Perforating wounds of the abdominal wall without puncture of an intra abdominal viscus is a much less important source of peritonitis.

PATHOGENESIS

The normal peritoneum possesses surprising natural powers of resistance to infection. Among experimental workers it is a well known fact that it is difficult to produce fatal peritonitis

CLASSIFICATION OF PERITONITIS

I Primary

A Secondary

P Primary

II Secondary

A Diseases of the digestive tract

1 Appendicitis

1 Intestinal ulcers and inflammation

Tuberculosis

b Sporadic perforations

1 Typhoid fever

Tuberculosis

3 Diverticulitis

4 Stomach malignancy

Nonspecific perforations

1 Duodenal fistula

perforation from lesions such as

ulcers, obstruction, etc.

cep

3 Gallstones

Perforation of the

b Perforation of the stomach

duodenum

B Lesions of the liver

1 Septicemia

Pyogenic sepsis

1 Gallstone abscess

4 Traumatic perforation of the liver

C Lesions of the biliary system

1 Suppurative cholecystitis

Biliary peritonitis

3 Peritonitis

4 Perforation of the gallbladder

D Lesions of the genitourinary tract

1 Intestinal perforation leading to peritonitis

seminal vesicles and kidneys

E Miscellaneous types of peritonitis

1 Peritonitis

Operative trauma

b Spontaneous perforation of the intestine

Leakage of bile

d Contaminated peritonitis

was due to

Perforation of the abdominal wall

3 Tuberculosis

by itself is capable of producing mild peritoneal reaction. Altmeier found that the virulence of the aerobic bacteria associated with appendicitis peritonitis particularly *B. coli* could be greatly increased by the coincident injection through a large bore needle of many particles of autoclaved sterile tissue. For example if an avirulent strain of *B. coli* was injected along with many fine pieces of autoclaved brain or muscle tissue peritonitis invariably occurred.

It repeated or constant soiling occurs such as that produced by an unrepaired rupture of the intestine or a leaking anastomotic suture line the peritoneum is unable to withstand bacterial attack. The severity and extent of peritonitis secondary to spontaneous or traumatic perforations of the gastro intestinal tract vary not only with the size of the opening and its duration but also with its location. McLeney and his associates noted that the mortality rate with small intestinal perforation was much greater than with large intestinal perforation and emphasized the importance of two factors the irritating effect of digestive fluids of the small intestine and the greater viability of the bacteria in the small intestine. Tavel and Lanz made similar observations and believed that the more fluid content and greater motility of the small intestine favored the greater spread of any soilage. Bergh, Bowers and Wangenstein and Schmidt, Cuerni, Hidde and Adashek confirmed the observation that the lower ileal region is the most infective part of the gastro intestinal tract. Altmeier cited Kendall's statement that the ileocecal region is the cultural medium and incubator in which bacterial growth exceeds in both intensity and complexity that of any known medium. The alkaline contents rich in proteins and carbohydrates in solution are particularly suited for bacterial life and the relative slowness with which food passes through the intestines at this lower level favors continued bacterial growth. If the reactive powers of the peritoneum become depressed by disease or poor general condition its susceptibility to infection is increased. If the virulence of the individual strain of bacteria is relatively great infection will also occur.

Another and probably very important factor in the production of secondary peritonitis is the synergistic or cumulative

with *pure cultures* of those bacteria usually found associated with peritonitis unless excessive amounts of the culture are used Halsted working with the *Staphylococcus aureus* found that dogs did not develop peritonitis when a bouillon culture of this bacterium was introduced into the peritoneal cavity Benians was able to inject intraperitoneally into rabbits 2500 million living *B. coli* from a twenty four hour culture in saline suspension with no obvious ill effects nor any abnormality in the peritoneal cavity beyond slight injection Steinberg cited the inability of investigators to produce a fatal peritonitis by injections of saline suspensions of *B. coli* Behrendt³ was unable to produce peritonitis in animals by the injection of bacteria unless his animals were in poor condition

After studying the bacterial flora of the peritoneal exudate of 100 cases of peritonitis secondary to appendicitis Altemeier found that the great majority of both aerobes and anaerobes isolated from these cases failed to produce fatal peritonitis when pure cultures were injected into guinea pigs and rabbits All the evidence pointed to the fact that the mere presence of single strains of bacteria in the healthy peritoneal cavity usually does not cause peritonitis

There are additional factors necessary for the development of peritonitis in presence of contamination If the peritoneum is injured or devitalized by irritants heatures foreign bodies gastro intestinal enzymes bacterial toxins or trauma infection will occur in the presence of bacteria After failing to produce peritonitis in dogs by merely instilling bouillon cultures into the peritoneal cavity Halsted showed that the coincident introduction of a small piece of potato or the strangulation of a small portion of the omentum frequently resulted in peritonitis Similarly Benians found it necessary to inject *B. coli* suspended in gum tragacanth to cause peritonitis Steinberg and Goldblatt adopted this method of injecting a gum tragacanth suspension of living *B. coli* to produce peritonitis Regardless of its action whether it protects the bacteria from the protective powers of the peritoneum as originally thought by Benians or whether it successfully retains the bacteria within the peritoneal cavity as believed by Steinberg gum tragacanth is essentially a foreign body which

peritonitis and the reader is referred to articles by Meleney, Altmeier¹ and Bower² for a resume of the works reported in the literature upon this subject.

Summary of Facts Concerning Bacteriology of Peritonitis

It is obvious that there is still considerable confusion concerning the individual constituents of the bacterial flora of secondary peritonitis. The variations in different studies suggest some geographic differences in bacterial flora but certain facts concerning the etiology of peritonitis seem to be well established.

1. Regardless of the primary etiology of the lesion of the gastro intestinal tract once perforation has occurred the number and variety of bacteria resident in that region of the tract will contaminate and infect the peritoneal cavity.

2. For this reason the bacterial flora of these cases presents a very complicated and bizarre picture. Among the *aerobes* recovered by Altmeier were *B. coli*, streptococci, *B. pseudo-diphtheriae*, staphylococci, *B. lactis aerogenes*, *B. proteus*, *B. alkaligenes*, *B. subtilis* and *B. mesentericus* and among the *anaerobes* were *B. melaninogenicum*, streptococci, gram negative diplococci, *B. thetoides*, *B. fragilis* and members of the clostridium group. In Meleney's series the average case presented from two to as many as six different strains of microorganisms. Of the twenty three different species isolated by him *B. coli*, the green producing streptococcus and *Cl. welchii* were the most common. In Altmeier's series it was found that three or more species were recovered from ninety six of the one hundred cases of acute perforated appendicitis and five or more species from fifty of the cases. Occasionally as many as seven were recovered. In every peritonitic exudate which was carefully investigated bacteriologically yielded at least one bacterium and in no instance was an entirely negative culture obtained. Sixteen different species of aerobic microorganisms and eighteen of anaerobic microorganisms were described in the purulent exudates taken from the immediate vicinity of the perforated appendix. *Bacillus coli*, aerobic streptococci, *B. melaninogenicum* and anaerobic streptococci were most frequently isolated.

action of the numerous intestinal bacteria growing in symbiosis. Later this factor will be further discussed.

BACTERIOLOGY

As has been mentioned previously, the primary peritonitides are monomicrobial infections caused usually by either the hemolytic streptococcus or the pneumococcus and are relatively rare.

In secondary peritonitis, however, the etiology is much more often of *polymicrobial* origin. In the early studies of peritonitis a misleading impression was obtained that secondary peritonitis was usually caused by the *B. coli* or the nonhemolytic streptococcus. The reasons for this conclusion are easily understandable. Originally, only aerobic cultures were made and in fact today this is still the practice in many hospitals throughout the country. The failure to understand the partial tension or anaerobic requirements of many bacteria and the special media necessary for growth of the more delicate bacteria naturally reduces the positive cultures to only the more easily growing and hearty strains of aerobic bacteria. Another prevalent practice which has greatly retarded the study of the bacterial flora consists of taking a specimen of the peritoneal exudate at the operating table and then allowing several hours to elapse before its inoculation into appropriate media. This permits drying of the specimen from continued exposure to the air and results in death of the less hardy aerobes and nonsporulating anaerobes. This practice is responsible for many false negatives or incomplete reports. Unless the specimen is promptly placed upon suitable media, the results are of limited value.

In peritonitis secondary to *nonperforating* lesions, the peritoneal fluid may be sterile, but it is a well established fact that when the intestinal wall becomes devascularized through injury or impaired circulation, bacterial growth may extend through the wall in the absence of gross perforation. In peritonitis secondary to *perforating* lesions of the gastrointestinal tract and its appendages, careful examination not only reveals positive bacterial growth but myriads of bacteria of two or more different strains. Many different species have been isolated from

peritonitis and the reader is referred to articles by Meleney⁶ Altemeier⁷ and Bower⁸ for a resume of the work reported in the literature upon this subject

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With better means of anaerobic cultivation the anaerobic flora of secondary peritonitis is becoming more prominent. Recently the black pigment producing anaerobe *B. melanogenicum* has been described for the first time in secondary peritonitis. It is usually found growing in very close association with the anaerobic or facultative anaerobic streptococcus from which it is separated with great difficulty. Consistent detection of this organism is only possible when the specimen is inoculated into appropriate media immediately or within five to ten minutes after it is taken. Its importance is not known.

3 The more clinically severe cases of acute secondary peritonitis occur most frequently in those having two or more infecting organisms. Meloney found the disease worse in almost every respect when more than one bacterium was present. Altemeier¹ found the most severe cases had five or more infecting microorganisms and in no instance did a case from which only one bacterium was recovered, terminate fatally. This fact is of considerable prognostic importance. Meloney and his associates found that when smears of peritoneal fluid show no organisms and cultures yield no growth or fewer species appear in culture than were seen on smear the prognosis is very good. The percentage of mortality increases rapidly when more than one organism is seen on smear or is grown out in culture.

4 Essentially the same organisms can be isolated from associated secondary or metastatic abscesses in remote areas of the body.

5 The ascription of the average case of peritonitis to the unaided activity of *B. coli* or other single strains seems to be without sufficient justification.

6 The great majority of these bacteria will not produce fatal peritonitis when injected in pure culture in experimental animals unless injected in large amounts or along with vitalized tissue.

7 These bacteria seem to exist in the intestinal content in a peritoneal condition state of symbiosis.

8 A definite synergistic cumulative pathogenic action

of these organisms growing in symbiosis has been demonstrated in experimental animals by Meleney and his associates and Altmeier⁴

9 The experiments of Weinberg, Prevot, Davesne and Renard³ of Meleney, Olpp, Harvey and Jern¹ and of Altmeier⁴ indicate that *peritonitis secondary to appendicitis* is a polymicrobial disease caused by the synergistic pathogenic action of a group of symbiotic bacteria. It appears that slightly or apparently nonpathogenic microorganisms may play an important part in the course of the peritonitis by increasing the virulence of the bacteria with which they are associated.

10 *Peritonitis secondary to the escape of bile or gastric duodenal juices* is principally chemical in nature during the first eight to twelve hours. Thereafter infection almost invariably appears as an accompanying feature.

11 The correlation of clinical and experimental investigation shows that in general the greater the number of intestinal bacterial species actively growing in the peritoneal exudate the greater the severity of the peritoneal infection is likely to be.

Importance of Anaerobic Peritonitis

The importance of the anaerobes in peritonitis is not clear. Weinberg and his associates divided all investigations on the bacteriologic flora of appendicitis prior to theirs into three periods. In the first aerobic organisms alone were isolated; in the second the anaerobic bacteria were given the chief role; and finally in the third efforts were made to determine the role played by each organism found in the complex flora. At the present time we may add a fourth period in which the pathogenic action of the various organisms is being determined collectively as well as individually. Meleney³ has found that the presence of *Clostridium welchii* per se in the peritonitic exudate does not increase the severity of the infection. Likewise the experiments of Altmeier⁴ indicate that the presence of other individual strains of anaerobic bacteria such as *B. melaninogenicum*, anaerobic streptococci, *B. thetaioides*, *B. fragilis* and

Other members of the clostridium group do not necessarily indicate a graver prognosis. Usually the collective action of several strains seems to be the important pathogenic factor.

One property of many of the anaerobes is the ability to attack and tear down native proteins with the production of various foul odors. In fact the prevalent idea that the *B. coli* is responsible for the characteristic foul odor of peritonitis secondary to perforation of the appendix or intestine is erroneous. The *B. coli* by itself is unable to attack native human proteins. It can and does break down split protein products such as peptone and tryptone to produce indole. Pure indole does not have a putrid odor but has in fact an aromatic odor. Cases of peritonitis may have the characteristic foul odor in the absence of *B. coli*.

In 1938 Altmeier¹ studied the ability of *B. coli* to produce a putrid odor when grown upon sterile human pus and found that no foul odor resulted although a very good growth of the bacterium was obtained. On the other hand when similar pus was inoculated with *B. melanogenium* and the anaerobic *Streptococcus putrificus* a marked penetrating foul odor was produced after three days incubation under anaerobic conditions. In addition to these other anaerobic organisms recovered from the pus of peritonitis are capable of producing foul odors. These organisms include various members of the clostridium group, *Streptobacterium foetidum*, *B. thetoides* and other forms of unidentifiable gram positive and gram negative bacilli. He concluded that the characteristic putrid odor is caused by the presence and growth of anaerobic bacteria chiefly *B. melanogenium* and anaerobic streptococci.

In peritonitis secondary to female genital tract lesions two main groups are recognized one which follows gonorrheal salpingitis and the other which is associated with puerperal sepsis or septic abortion. In the first group the gonococcus is the etiologic agent but in the second group a mixed aerobic and anaerobic bacterial flora is usually found. The aerobes generally encountered are hemolytic and nonhemolytic streptococci, staphylococci, *B. coli* and diphtheroid bacilli. The anaerobes are mainly various strains of streptococci. Schott

müller's *B. symbiophiles*, diphtheroid bacilli and *B. melaninogenicum*. The hemolytic streptococcus and the anaerobic streptococcus are thought to be responsible for the severity of this type of peritonitis. Schottmüller, since 1910, has repeatedly claimed that the important etiologic agent of puerperal sepsis is the anaerobic *Streptococcus putridus* and similar findings have been reported by Bingold, Schwartz and Dieckman, Colebrook and Hare, and Schwartz and Brown, although they recognized the importance of strains of an aerobic streptococci other than *Streptococcus putridus*. In many cases of puerperal sepsis with peritonitis the anaerobic streptococcus can be isolated not only from the peritonitis exudate but also from the blood stream.

Another occasional source of peritonitis caused by the anaerobic streptococcus is that following spontaneous rupture of a *chronic tubo-ovarian abscess* or operative interference for such an abscess. Although the pus of these chronic abscesses is frequently considered sterile, the anaerobic streptococcus in pure or mixed culture was recovered in twenty-two of twenty-five consecutive cases by Altemeier. One of the cases studied developed a fatal postoperative peritonitis after salpingo-oophorectomy. Although most investigators have found that these anaerobic streptococci have little or no virulence for laboratory animals, their frequent presence often in pure culture in human inflammatory lesions strongly suggests their pathogenic nature for man. Considerable more work is needed in this field.

TOXEMIA OF PERITONITIS

At least two factors seem to be active in the production of the toxemia of peritonitis: *absorbed bacterial toxins* and *hemolysis* secondary to effusion of large amounts of exudate into the peritoneal cavity with resultant alterations in blood chemistry. In a series of experiments on dogs, Harmon and Harkins demonstrated that the peritonitic exudate contains a factor which depresses the blood pressure when filtered and injected into other animals. They showed that this depressor substance was also present in bacteria-free filtrates of *B. coli* and *C. welchii* cultures and in nonprotein extracts of these filtrates.

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quently occur. Numerous attempts have been made to devise methods of preventing this complication. Vaccines have been extensively employed by Mikulicz, Barger, Dixon, Rankin, Steinberg, and his associates. Collier and Rife and others. Mikulicz used *B. coli* vaccine but was forced to discontinue its use because of severe reactions. Barger in 1938 prepared a vaccine from *B. coli* and streptococci which was injected intraperitoneally three days before intestinal resections. Dixon and Barger reported that the mortality rate from postoperative peritonitis dropped 66 per cent in 1500 patients subjected to this vaccine therapy but Rankin reported he had abandoned the use of this intraperitoneal vaccine because he had further reduced his mortality rate by other preoperative measures. Steinberg and his associates have been successful in preventing experimental peritonitis in dogs by the intraperitoneal injection of *Bactragen* a suspension of *B. coli* vaccine in 1 per cent gum tragacanth. This protection is produced by a local hyperleukocytosis within the peritoneal cavity. According to Steinberg and his associates the effectiveness of this protection is determined by a mobilization of a sufficiently large number of phagocytic polymorphonuclear leukocytes which requires the retention of an active leukocyte evoking antigen in the peritoneal cavity. They have reported the apparently successful use of *Bactragen* prophylactically in humans. Jones, however, stated that he had had two deaths with bloody peritoneal fluid after using the vaccine and had therefore avoided its further use.

The intraperitoneal instillation of many other sterile irritants has been shown to afford some degree of peritoneal protection against infection. Such substances include saline solution, glucose solution, blood serum, broth, bovine amniotic fluid, egg albumen, sodium ricinoleate, ether and tincture of merthiolate.

Recently evidence is accumulating that the intraperitoneal instillation of *sulfanilamide* appears to give considerable protection against peritonitis in the presence of bacterial contamination. Varco, Hoy, and Stevens demonstrated a lower mortality rate in dogs following gastro-intestinal anastomoses when *sulfanilamide* was used. Altmeier found that 75 per

Okada studied the blood chemistry of dogs with experimental peritonitis. He found an increase of nitrogen, increase of viscosity, decrease of blood chlorides, delayed clotting time and delayed sedimentation rate. He concluded that histamine picrate, which he found in the exudate, is probably the important cause of death in peritonitis.

In animals with diffuse peritonitis Imanaga found a lowered hydrogen ion concentration and lowered sodium chloride and oxygen content of the portal venous blood.

Harkins, Harmon and Hudson estimated the exudation in bile peritonitis to be approximately one third of the blood volume and 60 per cent of the plasma volume, with resultant marked hemoconcentration.

Blalock found that the intravenous administration of saline solution in dogs with experimental peritonitis caused a marked increase of the peritoneal exudate, while the subcutaneous did not.

PREVENTION OF PERITONITIS

Postoperative peritonitis is still the most dreaded complication of abdominal surgery. There is no question but that good diagnostic ability, surgical technique, judgment and experience minimize the development of postoperative peritonitis. Adequate preoperative preparation of the patient restores him to a state approximating normal and increases his general resistance. Injury or devitalization of the intraperitoneal tissues is reduced to a minimum by gentle handling of the intestines and peritoneum, avoidance of strangulation and large bites of tissue by ligature, sharp dissection when possible and careful preservation of the intestinal blood supply. The avoidance of bacterial contamination of the peritoneum is principally a matter of operative skill, particularly in intestinal resections and anastomoses. The danger of peritonitis develops after intestinal resection in the presence of obstructions well recognized unless a preliminary decompression is done.

However, there are many intra-abdominal lesions in which the bacteria have extended beyond the wall of the intestine into the adjacent tissues, such as a carcinoma of the colon. Under such conditions bacterial contamination and infection fre-

ACTIVE TREATMENT OF PERITONITIS

The successful management of peritonitis is based upon *early correct diagnosis adequate preoperative and postoperative care good surgical judgment and technical skill*. The controversy over prompt operative and conservative or delayed operative treatment continues but it is our policy to operate promptly in most cases of peritonitis removing the focus of infection or suturing the gastro intestinal perforation with a minimum of trauma. *Preoperatively* if the patient shows signs of dehydration or toxemia adequate parenteral fluids (5 per cent glucose and saline) are advocated. In the case of perforated appendicitis the appendix is removed through a small McBurney incision if this can be done safely without spreading the infection. In making abdominal incisions for peritonitis we believe it is important not to dissect back any of the various layers any more than is absolutely necessary as this exposes greater areas of the abdominal wall to contamination and infection by the bacteria in the peritoneal exudate.

The question of *drainage* is decided upon the merits of each individual case. In the presence of foreign bodies such as fecal contamination or devitalized tissue drainage is advocated by Reid. In addition we consider the presence of a foul smelling peritoneal exudate to be indicative of the presence of anaerobic organisms and unless drainage is instituted secondary abscesses are prone to develop.

Postoperatively the use of Fowler's position continuous gastric suction interval doses of morphine and repeated small blood transfusions are important. A positive fluid electrolyte and serum protein balance is carefully maintained. Fluids by mouth are restricted until peristalsis has been reestablished.

The value of specific drug therapy in peritonitis has not been proved but evidence of its worth is rapidly accumulating from many sources. In primary peritonitis Ladd Botsford and Ciminelli believe the high mortality rate in children can be markedly reduced by adequate *sulfonamide treatment* in addition to early peritoneal drainage and type specific serum. Recently the use of sulfanilamide in the prophylactic and therapeutic treatment of peritonitis has been adopted at the Cincin-

cent of rabbits were protected from a virulent mixed culture of bacteria when sulfanilamide was instilled intraperitoneally along with the bacteria. If instillation was delayed it apparently had little protective action. Rea also concluded that sulfanilamide seemed to be most effective in the preperitonitis stage and that its efficacy was much reduced once peritonitis had become established. Likewise Schnidt, Cuerni, Hidde and Adashek found that the earlier this drug is administered the better are the results obtained. Lockwood and Rhoads² believe that the peritoneum is a favorable site for the action of sulfanilamide and they have obtained good results clinically in the prevention and treatment of peritonitis. Lockwood and Ravdin have used sulfanilamide prophylactically in surgery of inflammatory and traumatic bowel perforations.

There is evidence that a nonspecific type of peritoneal immunity can be produced by the application of *roentgen irradiation* over the abdomen one month preoperatively. No postoperative peritonitis occurred in fifty-one consecutive cases of resection for carcinoma of the rectum and rectosigmoid reported by Pratt with one exception when an operative error in the selection of the point of ligation of the vessels resulted in extensive gangrene and sloughing of the colon. All of these patients had received high voltage roentgen therapy one month preoperatively primarily to decrease the size of the carcinoma and to protect against metastases. Altemeier and Jones³ studied the protective value of x ray against extremely virulent peritonitis in rabbits. From their experimental results it appears that high voltage roentgen therapy given four to seven weeks before the intraperitoneal injection of virulent bacteria protects from 70 to 75 per cent of the rabbits from experimental peritonitis. The manner in which this protection is produced is obscure. Rea found that x ray irradiation three days before inoculation of bacteria gave little or no protection from peritonitis.

The evidence that *bacteriophage* and specific antisera can be used prophylactically in human peritonitis is slight. The mixed and bizarre bacterial flora definitely seems to limit the value of these agents.

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nati General Hospital. The sterile sulfanilamide powder is dusted into the wound and peritoneal cavity at the time of operation using 8 gm for the peritoneum and 4 gm for the wound as an adult dose. Postoperatively the sulfanilamide blood level is carefully watched and in the more severe case is maintained by the additional administration of sulfanilamide parenterally.

We have had no experience with the *roentgen treatment* of peritonitis as reported by Kelly and Dowell⁴ or with *sero-therapy* as advocated by Vincent, Weinberg, Prevot, Davesne and Renard, Riemann, Kunz,⁵ Priestley and McCormack⁶ and many others.

CONCLUSIONS

Investigations of human and experimental animal peritonitis have resulted in a better understanding of the principles governing successful treatment and of the factors active in the determination of the nature and severity of the individual infection. The practical application of these results has undoubtedly been a factor in the reduction of the mortality rates (cf recent reports).

We wish to emphasize the importance and advantages of adequate bacteriologic control as a part of the surgical treatment of peritonitis. Careful cultures with aerobic and anaerobic and diagnostic and prognostic smears of the purulent exudate are of particular value.

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INFECTIONS OF THE HAND

MICHAEL L. MASON M.D. Ph.D. F.A.C.S.†

It is impossible to discuss infections of the hand without leaning heavily upon the basic contributions made by Allen B. Kanavel. He brought to this field a broad conception encompassing the fundamental sciences of anatomy, physiology, bacteriology, and the entire clinical picture including the reparative surgery of the complicating sequelae. Back of all of this was Kanavel's insistence that the surgeon who cares for an infected hand appreciate that he is dealing not only with an infection but also with a motor and sensory organ upon the efficient functioning of which the individual's livelihood depends.

FREQUENCY AND IMPORTANCE

There are many reasons why injuries and infections of the hand have been accorded special consideration. Industrial statistics, as emphasized by Probst, have shown that they cause more loss of working time than any single condition. Probably 50 per cent of all industrial injuries involve the hand. It has been estimated that the incidence of infections of the hand is 3 to 7 per 1000 of population each year and that the mortality is about equal to that of acute appendicitis. Injuries and infections of the hand affect individuals during their productive years, at least 70 per cent occurring between the ages of twenty and fifty.

It is hardly necessary to emphasize the great *functional value* of the human hand. The means of livelihood of most of us would be taken away by loss of its use. Many patients have had to change their occupations because of disability following injury or infection. The functions of the hand are such

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INFECTIONS OF THE HAND

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It is impossible to discuss infections of the hand without leaning heavily upon the basic contributions made by Allen B Kanavel. He brought to this field a broad conception encompassing the fundamental sciences of anatomy, physiology, bacteriology, and the entire clinical picture including the reparative surgery of the complicating sequelae. Back of all of this was Kanavel's insistence that the surgeon who cares for an infected hand appreciate that he is dealing not only with an infection but also with a motor and sensory organ upon the efficient functioning of which the individual's livelihood depends.

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that even slight disturbances in motion or sensation lead to serious even irreparable disabling handicaps. One need only consider the significance of slight fibrosis about the interphalangeal joints in a violinist or the loss of sensation in the finger tip in a surgeon. This vulnerability to slight disturbances and the manifestations and course of infections can be readily appreciated when one considers the evolution and anatomy of the hand. Nature has developed in the hand a finely coordinated motor and sensory organ which has made possible our present civilization. The hand is composed of compact and efficiently balanced muscles, tendons and joints, motor and sensory nerves and specialized nerve endings. Bulk and protection are sacrificed to efficiency; there is nothing to spare. Each part is essential and reduced to a minimum.

The hand, uncovered and unprotected, touches and feels and works with all the objects of our external life. It is subject to mechanical, chemical and thermal injuries and is exposed to all types of bacteria. The doctor, the dentist, the nurse and the pathologist must take particular precautions to avoid contamination with virulent organisms. The thick, tough palmar skin favors bacterial nests and tends to force infectious processes deep into the tissues rather than to allow them ready egress. The blood supply, in comparison to other parts of the body, is poor and the surface temperature of the hand is several degrees lower than body temperature.

It is factors such as these which explain why infections of the hand are so frequent and so important, why recovery from them is often slow and tedious and why treatment may call for considerable skill and expert clinical judgment.

PROPHYLAXIS

With rare exceptions infections of the hand follow injuries and the proper treatment of the open wound becomes the prophylactic treatment of hand infections. Whether or not an infection will develop in a wound depends upon two factors—the presence of virulent bacteria and the resistance of the tissues to microorganisms. Both factors are variable and to a greater or lesser extent the surgeon may weight the scales in favor of one or the other.

Avoidance of Contamination—Pulaski, Meleney and Spaeth have shown that open wounds are always contaminated often with two or more varieties of bacteria. Even the clean operative wound harbors organisms. That wound infection or postoperative infection does not occur in all open wounds is due to several factors. The surgeon is beginning to appreciate that the majority of bacteria found in wounds are either non-pathogenic or are invasive only if there has been an excessive amount of tissue injury. This is true even for the ubiquitous streptococci and staphylococci. Certain types of these bacteria are extremely virulent and immediately invasive others are relatively harmless unless present in large numbers or in markedly damaged tissues while still others seem to have no pathologic significance. Those which are primarily invasive for human tissues are found particularly in association with man on the skin in the nose and throat or as causative agents in various infectious processes. The occurrence in nature of these invasive organisms seem to be quite rare as evidenced by the work of Hare in Toronto. It seems therefore that the initial inoculation of open injuries with bacteria of this type would be quite rare although it may take place. The immediately invasive character of such bacteria is illustrated by cases of wounds sustained by injuries with human teeth, tonsil snare safety pins from infected cases, per stirpem injuries from patients with sepsis and so forth. The rapidity of development of infection in such cases is startling.

With the exception of such wounds as noted initial virulent inoculation seems to be rare. We have come to fear more the secondary contaminants from dressings, fingers, nose and throat of some individual or even from the patient himself which gain entrance into the wound after it has been sustained. It seems to me obvious that one of our first concerns in the management of the open wound is to prevent secondary contamination not so much because it might give rise to a mixed infection but because it might introduce virulent bacteria into a wound contaminated only with relatively harmless ones. Hence *strict asepsis* and *avoidance of contamination* from the time of first aid until healing has occurred becomes one of the first principles of prophylaxis of infections of the hand. In

this connection the reports by Miles and associates and the various studies by Hirschfeld are of significance

Avoidance of Tissue Damage—The resistance of the tissues to invading bacteria is another concern of the surgeon in both the prophylactic and actual cure of hand infections. Healthy tissues can deal with many types of even quite virulent bacteria provided the organisms are not present in too great numbers. Devitalized tissues may fall prey even to relatively virulent bacteria. Tissue damage however may occur not only at the time of injury but also subsequent to the injury as a result of the use of chemical antiseptics, operative trauma or failure of the surgeon to put the part at rest following proper treatment of the wound. Wound excision which removes tissue hopelessly damaged by the initial injury should leave behind only healthy tissues capable of dealing with any organisms still present. However, if the surgeon leaves in his wake masses of tissues crushed in hemostats and ligatures, there is of devitalization due to forceful retraction or irritant chemicals and if the patient further traumatizes the part, infection is likely to supervene.

It would seem unnecessary to emphasize in this discussion these basic principles of surgery. However, considerable experience with infections of the hand has forced me to the conclusion that only some 10 per cent of hand infections follow the initial inoculation of very virulent bacteria, whereas in the remainder secondary contaminants lowered tissue resistance or both are at fault. The proper management of injuries of the hand therefore is the prophylactic treatment of infections of the hand (and parenthetically the proper management of trivial infections is the prophylactic treatment against the major infections). A large majority of all hand infections can be traced to avoidable contamination and unnecessary tissue injury.

GENERAL CONSIDERATIONS IN TREATMENT

Success in the management of an infection of the hand depends upon three factors: early and accurate diagnosis, prompt institution of the best and most efficient means of treatment, and the conservation of the function.

Early and Accurate Diagnosis—The correct diagnosis again involves three things. First the determination of the location of the infection and a visualization of its possible routes of extension. Second the determination as to whether or not the infection is localized or spreading—a distinction of the greatest importance since the treatment of one type is diametrically opposed to that of the other. The third factor in the diagnosis is the identification of the infecting organism. In some instances successful treatment may depend entirely upon the identification of the bacterial invader.

If we wish to take intelligent advantage of the various sulfonamide drugs and of zinc peroxide we must know not only whether the organisms are aerobic or anaerobic but also the various groups and types to which the bacteria belong.

Prompt Institution of Treatment—The prompt institution of treatment does not mean necessarily that incision is made as soon as the diagnosis is certain. In some infections like tenosynovitis and felon early incision is indicated since otherwise tissue destruction and extension take place. In the spreading infections the utmost conservation is demanded.

Conservation of Function—Conservation of function of the hand involves a knowledge of the movements of the hand and an appreciation of its importance as a peripheral sense organ. During the acute stage of the infection while the warm moist packs are used the hand should be prevented from assuming vicious positions and should be maintained in the position of function whenever strict immobilization is indicated. As soon as voluminous warm packs can be dispensed with the hand may be soaked once or twice daily in a warm sterile arm bath and during this time the patient is instructed to move the fingers and wrist to prevent the development of stiffness and to discourage fibrinous adhesions. Dressings following the acute stage should be light and nonconfining. Uninvolved fingers and joints should be left free to move and the patient encouraged to move them. The incisions made to secure drainage are based on a consideration of their possible after effects. They should be so placed that the resultant scar does not involve important tactile surfaces nor lead to disabling contractions.

There are certain other general considerations which apply equally to all infections.

Anesthesia—A general anesthetic should be used in all instances except for superficial accumulations of pus which may be released by the removal of the cuticular layer of the skin. *Freezing with ethyl chloride* does not permit adequate incision before intolerable pain begins nor does it allow the surgeon adequately to visualize the abscess cavity or identify important anatomic structures. The freezing also lowers the local tissue vitality and cannot exert a favorable effect upon tissue resistance. The injection of *local anesthetics* into or about inflamed areas tends to increase tension in the tissues and may easily carry bacteria into noninvolved regions. Acute spreading infection of the hand is a not infrequent sequel to a local anesthetic infiltration and we have seen a fair number of cases in which gangrene of the finger tip has followed local infiltration. Kraufman has recently reviewed a series of such cases. Most incisions on the hand require slow careful step by step technique and this can be accomplished only under *general anesthesia*. The newer *intravenous* anesthetic agents are finding a field here and appear to be replacing gas anesthetics for short operations. The surgeon who feels forced to avoid a general anesthesia might profitably turn to intravenous

Hemostasis—A bloodless field is almost indispensable in all operations upon the hand. Identification and avoidance of important nerves, blood vessels and tendons cannot be made if the operative field is constantly flooded with blood. A dry field can be obtained by the use of a blood pressure apparatus inflated to 50 to 60 mm of mercury following a thirty second elevation of the arm. The broad cuff applies an even controlled pressure over a wide area and does not cause nerve injury even if left on for a considerable period of time.

Drainage—Drainage is secured by adequate incision and not by the use of foreign material introduced into the wounds. Drains are useful to prevent the accumulation of fluid which might occur immediately after incision. After twenty four to forty eight hours they should be removed and not reinserted since there is no more certainty of introducing secondary infection or keeping up discharge than by the

constant reintroduction of wicks and plugs. The drainage material should be of soft and nonadherent material such as rubber strips or vaseline gauze which do not lead to pressure injuries and may be easily removed. It should be simply tacked into the edge of the wound and not packed in.

Incisions—There are certain guiding principles to be followed in making incisions on the hand. Incisions should be as large as is necessary to secure adequate drainage. The surgeon should know the anatomy of the hand so that he may avoid important structures and not convey infection from an involved area into a noninvolved one. It is an easy matter to convert a felon into a tenosynovitis if the knife is carried too far proximally when incising the anterior closed space. The scars following healing of an incision should not lie on an important tactile surface e.g. in the midline of the pulp. Incisions so far as possible should follow the skin creases and avoid crossing them at right angles. The skin creases are natural lines of folding and tension is minimal along lines parallel to these folds while it is greatest at right angles to them. Incisions at right angles to the natural creases heal with a minimum of scarring and contraction whereas incisions at right angles to them tend to produce thick and contracting scars. Particularly to be avoided are midline incisions on fingers and wrist which lead to flexion deformities. Midline incisions on the fingers make for drainage of tenosynovitis allow the tendons to herniate forward with ensuing irreparable damage.

Incisions which have been found advantageous for drainage of the hand are illustrated in Fig. 11. It is to be observed that the incision for lumbrical canal abscess and middle palmar space infection is *transverse* instead of longitudinal. This is because the longitudinal incision while efficient contracts heavily and leaves more scar than the transverse type. McKeim has pointed out the advantages of transverse incisions in the palm. The transverse incision must of course be made with extreme care since it crosses the nerves and tendon and must be made in a bloodless field as should all incisions on the hand.

Immobilization of Injured Part—The great value of rest in controlling infections is well illustrated in infections of the hand. *Splints* should be an integral part of the dressings and

should be worn by the patient until the infectious process has healed. If one needs to be convinced of this fact he should only observe the response to rest of the usual finger tip injury first seen with redness and discharge three to four days after the accident when the patient has used the finger even though it has been covered with dressings. Such infections if dressed carefully and the finger put on a splint will rapidly subside.

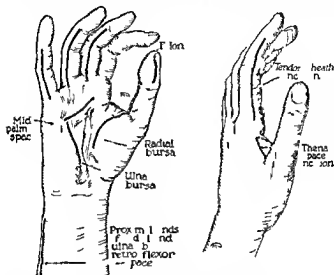


Fig 11 -I f dra g f h d h th d f c l p
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pl 1939)

Similar experiences with all kinds of infection of the hand will soon convince the surgeon of the great value of immobilization.

It would be impossible to describe all of the splints which will be found useful but a few of the more common ones can be briefly mentioned. Splints may be made of aluminum sheet cut with tin snips to desired size and shape rounded out on an anvil and smoothed off with file and emery cloth (Figs 118-119). Simple finger splints 6 to 7 inches long and

inch wide are valuable and a good stock of them should be made up and kept on hand. They may be applied over the dressings on the volar or dorsal surface of the finger and should be bent so as to keep the digit slightly flexed at each joint. As a general rule fingers should not be immobilized in



Fig 118—Al m m pl f mm bl f d fi N t h
 d d m d l f g rs m bl d b h l gh fl h t th
 n t h ld k p p d l h m g f g rs f

a straight position since this allows the capsules of the joints to contract in extension and is also often quite painful.

The simple cock up splint fashioned so as to hold the hand in a position of function is particularly valuable when it is not necessary to immobilize the fingers (Fig 119). If fingers, wrist and thumb are to be immobilized as they are when placed in warm moist packs a large aluminum sheet is cut in such a fashion that the whole hand rests upon it in a position of func-

should be worn by the patient until the infectious process has healed. If one needs to be convinced of this fact he should only observe the response to rest of the usual finger tip injury first seen with redness and discharge three to four days after the accident when the patient has used the finger even though it has been covered with dressings. Such infections if dressed carefully and the finger put on a splint will rapidly subside.

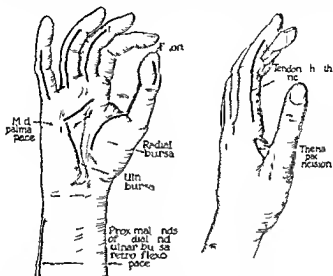


Fig. 117—1. Drawing of the hand and wrist showing the location of the M.d. palmar plexus, the radial and ulnar bursae, and the proximal ends of the distal ulnar bursa retro flexo plexus. (From the collection of the U.S. Army Medical Department, 1939.)

Similar experiences with all wounds and infections of the hand will soon convince the surgeon of the great value of immobilization.

It would be impossible to describe all of the splints which will be found useful but a few of the more common ones can be briefly mentioned. Splints may be made of aluminum sheeting cut with tin snips to desired size and shape rounded out on an anvil and smoothed off with file and emery cloth (Figs. 118-119). Simple finger splints 6 to 7 inches long and

importance. The subcutaneous infections of the fingers are relatively frequent and vary from small localized processes to extensive accumulations of pus which may entirely encircle a finger. The felon is extremely frequent more so than one realizes until a series of cases is studied. The acute spreading infections if we include in this group all cases which present lymphangitis are relatively frequent although the very fulminant cases are by no means common. Suppurative tenosynovitis is one of the most feared emergencies in hand infections but fortunately it is relatively rare and as a primary process (*i.e.* the immediate initial invasion of the tendon sheath by pin prick, knife cut and so on) is not at all frequent.

1 SUBCUTANEOUS INFECTIONS OF THE FINGERS

The importance of subcutaneous infections of the fingers lies in their frequency, in the possibility of their being confused with tenosynovitis and the possibility that if this differentiation is not made correctly a subcutaneous infection may be converted into a tenosynovitis or a suppurative tenosynovitis may not be recognized and the subcutaneous abscess only may be opened.

Subcutaneous infections start most often from tiny open wounds along the side, volar or dorsal surface of a finger (FIG 170) often on the middle phalanx. They may remain localized to one side of the phalanx but most often they tend to spread beneath the superficial fascia through the fat and areolar tissue over volar and dorsal surfaces. They may almost encircle the finger and may spread distally and proximally to involve most of the digit. When they occur about the proximal phalanx the pus may track upwards into the web space and even under the superficial fascia of an adjacent finger. Usually the process is of such a nature as to localize rapidly and lead to necrosis and unless drained after this localization has taken place they may rupture through the skin in several places producing a picture not unlike that seen in neglected tenosynovitis. If the process goes on untreated the tendon sheath of the finger may become involved and a *tenosynovitis* results. This tenosynovitis in contrast to that which follows primary inoculation of the tendon sheath may be localized to

tion It may be made so that the hand rests in pronation or in supination depending somewhat on the site of the infection After the acute process is over and if rest is still necessary a smaller splint may be made to support the wrist in dorsiflexion and whatever fingers are necessary in slight flexion leaving

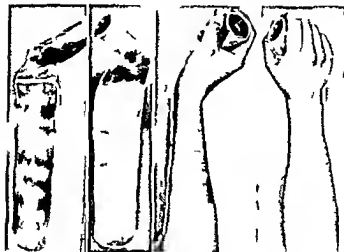


Fig. 119—5. (1) Plaster splint for dorsal wrist and hand. (2) Plaster splint for dorsal wrist and hand. (3) Plaster splint for dorsal wrist and hand. (4) Plaster splint for palmar wrist and hand.

the other fingers free When it is necessary to immobilize a finger it is usually advisable to immobilize the adjacent fingers in case of the index and little fingers only the middle and ring finger respectively need be splinted along with the immobilized one

SPECIFIC TYPES OF HAND INFECTIONS

It would not be possible to discuss all types of hand infections in this brief presentation I should like however to present four processes each of which will illustrate the points which I have attempted to make These processes are (1) subcutaneous infections of the fingers (2) the felon (3) acute spreading infections and (4) acute suppurative tenosynovitis I place them in the order of their frequency and quantitative

neous infections usually subside very rapidly following incision the application of warm moist packs and splinting. If a process supposedly a subcutaneous infection does not subside in good time after incision it usually means either that a tenosynovitis has been overlooked or that an osteomyelitis is present.

2 FELON

The anatomic peculiarities of the distal phalanx explain the symptoms and course of the felon (Fig. 121). The tough con-



Fig. 121

Fig. 122

Fig. 121 - N gl d f l f l f c th mb w h m k d ll g o
 f p d d os my l f d t l ph l S b d ft l p d
 g d ru f t d q st m L f f p d l d
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 Fig. 122 - D l l u f f l m p d g f
 l n g f m p y l y f l d r sum f th l t l f i g Af
 d gly t r my rs l l d p t rup cu l
 d rs m f t Compl ry h t d b l ry

nective tissue septa which bind the undersurface of the skin to the bone prevent expansion of the tissues. The pain in felon is therefore early and severe and the surgeon usually sees the patient within twenty-four to forty-eight hours of the onset. The same tension which causes the pain leads to interference with the blood supply and unless the tension is soon relieved necrosis occurs. The intimate association of the distal phalanx

in area of the sheath probably because the preceding inflammation has caused adhesions in the synovial sheath. In late cases the joints as well as the tendon sheath may be involved so that what started out as a relatively simple process may lead to the destruction of a digit.

Early the diagnosis presents little difficulty since the swelling is localized and there are not the cardinal symptoms of



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 b f d

tenosynovitis. Latron however when the finger is involved and especially if a sinus is present it may not be easy to make a definite diagnosis. Here the value of operating under general anesthesia and in a bloodless field is well emphasized. The surgeon can incise slowly and carefully and can actually inspect the sheath to see if it has been invaded. The ulcer

neous infections usually subside very rapidly following incision the application of warm moist packs and splinting. If a process supposedly a subcutaneous infection does not subside in good time after incision it usually means either that a tenosynovitis has been overlooked or that an osteomyelitis is present.

2 FELON

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Fig 121



Fig 1

Fig 121—N l d f l f l f d h m k d l l g is
f p d d my l f d l ph l S b d f p p d
g d ru f r d q est m L ss f f t p d l d
fi g t p
Fig 12—D rs l f al u f f lm p d g f n
l g f m p y j y f th d rs m f h lttl fi g Af
d gly rmy rs l l d p t ruptu
d rsum f Compl y h d b l tv

nective tissue septa which bind the undersurface of the skin to the bone prevent expansion of the tissues. The pain in felon is therefore early and severe and the surgeon usually sees the patient within twenty-four to forty-eight hours of the onset. The same tension which causes the pain leads to interference with the blood supply and unless the tension is soon relieved necrosis occurs. The intimate association of the distal phalanx

with the infected space and the blocking of its blood supply predispose to involvement of this bone

Early relief of tension is of course necessary and the indication is to divide the retinacula cutis which bind the skin to the anterior surface of the distal phalanx. This may be done by a *lateral incision* along one side of the phalanx sweeping the knife across the space about midway between the bone and undersurface of the skin and dividing the connective tissue strands. The fish mouth type of incision is unnecessary and leaves a scar across the pad of the finger which may be seriously disabling especially in performing fine acts. It is quite a nuisance to a surgeon. The midline incision which is so frequently seen does not adequately drain the space and leaves a sensitive scar on the tactile surface of the pad.

Some involvement of the bone is probably present in all but the very earliest cases. However as has been pointed out by Koch the bone is invaded by extension from soft tissue infection and the indication is to drain the soft tissues. To attack it surgically with chisel or curet only invites disaster carries infection deeper into the bone and converts a mild periostitis into a destructive osteitis. Great caution must be exercised in diagnosing osteomyelitis from the roentgenogram since slight areas of atrophy so often associated with disuse and neighboring infection are frequently mistaken for bone infection. Not only is the diagnosis frequently in error but the direct attack upon the bone leads to unnecessary sacrifice of bone and to upward progression of the process into uninvolved bone.

If the case is seen late and adequate soft tissue drainage has not been secured the lateral incision of the phalanx should be made. If loose sequestered bone is present it should be lifted out gently but the remaining bone should not be touched. With conservative management by *adequate drainage* of soft tissues permitting the bone inflammation to subside or go on to sequestration the distal phalanx may frequently be saved and involvement of the rest of the finger prevented. *Splinting* is of inestimable value in this condition.

The evil reputation of the finger may usually be traced to errors in management which have as their result progressive necrosis and consequent loss of soft tissue and bone from the

finger tip. Inadequate drainage even if accomplished early defeats its own purpose. Drainage too late may be adequate but there will already be present a sizeable plug of necrotic soft tissue from the pulp and invasion of the bone. The third error is operative attack upon the bone itself a procedure which simply assists bacteria in their invasion.

3 THE ACUTE SPREADING INFECTIONS

The acute spreading infections such as *lymphangitis* and *streptococcal cellulitis* are the most serious with which the surgeon has to deal. They frequently follow a neglected trivial injury or result from the direct inoculation of extremely virulent organisms from human sources. They are frequently seen in nurses, physicians and pathologists whose profession brings them in contact with sharp objects contaminated with virulent pathogenic bacteria. The organisms spread quickly through the lymphatics and often produce a generalized infection within a few hours. The lymphatic distribution of the upper extremity is such that bacteria introduced into the tissues on the volar surface of the hand traverse most of the tissues of the hand or finger to reach the dorsum where gaining entrance to a smaller number of larger vessels they pass over the dorsum of the hand and wrist into the forearm and arm.

Symptomatically most cases begin with a chill, malaise, fever and often prostration. The site of injury aches and throbs and pain radiates up the forearm and arm. Examination at the onset may show the focal point of the infection to be red, tender and swollen while the red streaks of lymphangitis indicate the extension of infection into the lymphatics of the extremity.

From this point on it is possible to divide the cases into four groups depending upon the outcome (Koch). If treated conservatively the first group which comprises the majority will completely subside without any localization taking place. In the second group the initial focus on the hand subsides but localization occurs in the axilla or in the subpectoral region. In the third group localization eventually takes place on the hand or forearm. When the initial lesion has been on the

dorsal surface the most frequent localization is on the dorsum of the wrist (Fig 1 2) A less frequent mode of termination of a dorsal lesion is as a diffuse subcutaneous liquefaction and cutaneous gangrene With the initial lesion on the volar surface localization occurs usually as a suppurative tenosynovitis often associated with a dorsal carpal abscess The fourth group of cases are the fatal ones These cases shown increasing toxemia and progression of the local process and go on to fatal termination regardless of efforts made to arrest the infection Too often however overzealous efforts at local treatment precipitate a fatal outcome

These infections must be treated with the *utmost conservatism* Local treatment should be limited to the application of warm moist packs (Fig 1 3 174) and no attempt should be made to obtain drainage until unquestionable evidence of localization occurs This localization may take several days or a week or more and even then it is frequently wiser to allow subcutaneous abscesses to rupture and drain spontaneously than to incise them In cases with infection starting upon the volar surface in which tendon sheath involvement is evident the temptation to incise early must be resisted until the rapidly spreading process and lymphangitis subside This requires considerable patience and fortitude since the surgeon is being goaded constantly to do something for the intolerable pain which such patients often suffer However under strict conservative management and sedation the advancing edema and the red streaks usually recede and the localization becomes evident The drainage of the tendon sheaths may be accomplished often ten to fourteen days after the onset with surprisingly favorable results

It is in this group of patients that one may expect benefit from the use of the *sulfonamide drugs* The majority of the acute spreading infections are streptococcal in nature and no doubt many will respond to chemotherapy A controlled series of cases however is not available and we cannot as yet say from our own experience whether the drug or the other measures of care have been the effective treatment I am under the impression that we are seeing fewer patients with acute spreading infections in the past few years than formerly but this has not been checked statistically Even if this is true one could

Fig 13

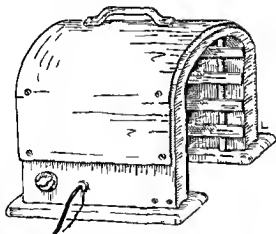
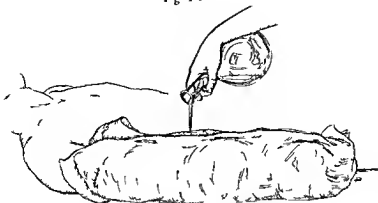


Fig 14

Fig 13—A. n. m. n. l. p. k. m. y. b. ppl. d. th. d.
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 um. by. h. rs. d. h. d. ss. g. k. p. t. n. h. t. by. th. p.
 b. k. (Γ. k. l. d. M. l. f. f. h. H. d. l. C. l.
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 1939)

Fig 14—Th. rape. u. b. k. m. n. temp. ratu. e. f.
 110. 140. Γ. f. m. m. st. les. gs. l. h. ld. b. d. h. ca. as.
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t e l D rar p es f spre d f infects hro l l
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not ascribe it to the sulfonamide drugs. Increasing interest in wounds and infections of the hand is being reflected in improved care and better results in general. One other fact also should be kept in mind in gauging the effect of the sulfonamide drugs in hand infections and that is that not all acute spreading infections are due to hemolytic streptococci nor are all hemolytic streptococci responsive to sulfonamides. Hence strict bacteriologic control of any process is necessary in assaying the value of the sulfonamides and no such studies are as yet available.

4 SUPPURATIVE TENOSYNOVITIS

I cannot at this time go into the *anatomy* of the tendon sheaths other than to recall hastily the salient facts concerning those on the volar surface of the hand and wrist (Fig. 175). These sheaths may be thought of as comprised of two groups—those enclosing the tendons of the index middle and ring fingers and those surrounding the tendons of the thumb and little finger. Those surrounding the digital portions of the tendons of the index middle and ring fingers extend only throughout the lengths of the fingers and end in the palm about 1 inch proximal to the web in relation to the deep fascial spaces of the hand—the *middle palmar space* in relation to the ring and middle finger sheaths and the *thenar space* in relation to the index finger sheath. When one of these three middle sheaths is infected pus is carried upwards into the palm and if rupture of the sheath occurs one of the palmar spaces becomes involved. The sheath of the flexor pollicis longus in turn as the *radial bursa* extends upwards through the wrist to end in the lower forearm. Here it lies in close

l p l l p l fl d d p t t h th p
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 n fi g) d g fi g Th dg l h h f ltrl fi g d th mb
 l h h ut d h gh h wrist t h
 f m g) b h rp Thes es k h l
 d d l b rs ly p u lly tu lly ct d h
 h f rt g l th th R ptu f
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relation to the large common sheath or *ulnar bursa* which encloses all of the other flexor tendons at the wrist and is continued downwards into the hand about the tendons of the little finger. Two important facts deserve emphasis. First these two large bursae are potentially or actually connected so that infection in one is quickly transferred to the other sheath. The other important consideration is that the two bursae end in the forearm and not in the hand. When rupture occurs pus is discharged into the deep fascial spaces of the forearm.



Fig 16—Symptoms and physical findings of tenosynovitis of the flexor digitorum profundus. The finger is held in slight flexion and any attempt to straighten it causes great pain (Fig 176). It is uniformly swollen and if it is gently examined the maximum tenderness will be found to outline the tendon sheath. The proximal cul de sac of the sheath produces moderate swelling in the palm and tenderness over this is especially significant. If the process has ruptured into a fascial space there are added to the above the findings of the space involvement. In the case of *ulnar space abscess* there is puffiness and induration over the first interosseous space and the

The symptoms and physical findings of tenosynovitis are typical and pathognomonic. The finger is held in slight flexion and any attempt to straighten it causes great pain (Fig 176). It is uniformly swollen and if it is gently examined the maximum tenderness will be found to outline the tendon sheath. The proximal cul de sac of the sheath produces moderate swelling in the palm and tenderness over this is especially significant. If the process has ruptured into a fascial space there are added to the above the findings of the space involvement. In the case of *ulnar space abscess* there is puffiness and induration over the first interosseous space and the

thumb is pushed away from the hand as if a rubber balloon were between it and the palm. If the *middle palmar space* (Fig 127) is invaded there will be tension and induration and the palm will be flattened. The skin over the middle of the palm will be grayish in color due to ischemia caused by the tension beneath.

In tenosynovitis *early incision* is indicated lest the process extend into the fascial spaces and to prevent if possible de-

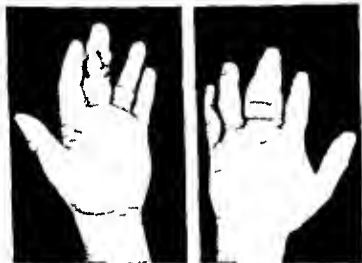


Fig 127—N gl d pp l t l M k d ll g f fi g f m ddl fi g b
l lm p l d d rs m fl and M ddl
l g f p lm d g yn f

struction of the enclosed tendons whose poor vascular supply makes them easy prey to necrosis. The *digital sheaths* may be opened by incisions well to the sides of the fingers either the whole length of the sheath as shown in Fig 117 or the distal portion of the sheath may be opened in the finger while the proximal cul de sac is opened by a transverse incision in the palm. The *ulnar bursa* requires three separate incisions one on the little finger a second in the palm and a third along the ulnar side of the forearm just above the wrist. The *radial*

bursa requires two incisions one along the ulnar side of the thumb and thenar eminence stopping an inch proximal to the transverse carpal ligament where the motor nerves to the thenar muscles cross the sheath and the other above the wrist on the radial side comparable to the ulnar incision. As a matter of fact the ulnar incision will usually drain both bursae effectively. The *middle palmar space* is drained through a transverse incision along the distal flexion crease of the palm the *flexor space* through an oblique incision along the radial border of the first dorsal interosseous muscle in a line connecting the metacarpophalangeal joints of the thumb and index finger.

The surgeon's responsibility does not end with the subsidence of the infection. The patient must be kept under observation and care until function has been restored to the hand. In the uncomplicated infections treated promptly and efficiently the after care is seldom prolonged. In the neglected case and in those with loss of tissues in which weeks or months are required to bring about subsidence of infection and healing *restoration of function* becomes the major problem. To take up this aspect of hand infections would encompass discussion of physical therapy, tension splinting, arthroplasties, skin transplantation and nerve and tendon repair. Suffice it to say at this time that the surgeon who recognizes the disabling potentialities of hand infections and follows correct principles in caring for injuries as well as infection will be less often confronted with the frozen hand which results from inflammatory fibrosis.

SUMMARY

Hand infections as infections elsewhere are dependent upon two variable factors: the bacteria and the tissues. Highly virulent bacteria may become invasive in the healthy undamaged tissues whereas bacteria of low virulence are often overcome unless in too great numbers by the natural resistance of normal body cells. On the other hand a central or intentional injury of a mechanical, chemical or thermal nature may so lower the resistance that infection occurs even from bacteria ordinarily non-invasive.

Rapidly invasive organisms almost always come from human sources after rather than at the time of injury and it becomes our concern to prevent such contamination of wounds or draining incisions by rigid observation of an aseptic technic. Secondary damage of tissues by irritant chemical operative trauma or use of the part may be avoided by careful technic avoidance of chemical antiseptics and purposeful splinting. In the care of an established infection the essential factors are early accurate diagnosis prompt institution of treatment and early restoration of function.

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THE CHEMOTHERAPY OF SURGICAL INFECTIONS

FRANK L. MELENEY MD FACS

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JOHN S. LOCKWOOD MD†

HISTORICAL DEVELOPMENT

EVER since it was suspected that certain diseases were caused by living organisms efforts have been made to destroy those organisms or prevent their activity by the local application, or the general administration of medicines. The development of infections in accidental wounds was observed and described as far back as recorded history and the Egyptian papyrus record elaborate prescriptions for the treatment of these surgical infections. The earlier efforts were chiefly confined to local applications of various infusions of herbs or alcoholic beverages and these were prescribed internally to fortify the body against such mishaps. The use of chemical like mercury for lesions which were probably syphilitic goes far back in medical practice. The value of quinine in malaria was folk lore in many countries without the benefit of medical science.

It was not until the causative organisms for infectious diseases began to be found in the 1870's and 1880's that this problem was attacked scientifically and systematically and while one group of investigators attempted to solve the problem by active immunization with vaccines and another by passive immunization with sera a third group led by Ehrlich ably supported by Hata and Kitasato tried to attack it by means of chemicals and Ehrlich has been generally recognized as

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† Ass	S g ry	Sch l	f M d		U	rs ty	f P	ns l
D	f l	Cl	H p l	f h	U	rs	f P	sy l

the Father of Chemotherapy. His long extended labors were not very successful with bacterial infections and it was only as a culmination of years of study that he finally succeeded in finding in *salvarsan* a new and better cure for syphilis. Ehrlich hoped that this would open the door to greater successes and in 1913 at the Seventeenth International Congress of Medicine in London he said: "I must be without being set down as an optimist put forward the view that in the next five years we shall have advances of the highest importance to record in this field of research." However in the next year the first World War broke loose scientific researches and investigations were abandoned and before the war was over Ehrlich was dead.

Although Ehrlich's success was largely with the higher forms of parasites spirochetes and protozoa a beginning had been made in the chemotherapy of bacterial diseases. Hata recognized the importance of thorough knowledge of the growth requirements and cultural characteristics of the causative organisms and of the pathogenesis of the diseases within the human body and the experimental animal. He paid this tribute to those who had initiated the science of bacteriology: "Had there not been the brilliant works of Lister, Pasteur, Koch and many other Ehrlich's results would never have been obtained."

Koch, Behring and others had been unsuccessful in their attempts to find chemicals which would be effective as internal disinfectants against bacterial diseases and had about come to the conclusion that it would be impossible. Hope was revived however when Morgenroth found *quinine* to have some therapeutic activity in pneumococcus infections and both German and Japanese observers noted that salvarsan had a curative action in cases of human anthrax. Ehrlich and Hata found that certain chemicals were very much weakened in their bacteriostatic action by contact with serum and they concluded that drugs capable of internal disinfection must be able to act as effectively in serum as in saline. They also observed that chemical substances seemed to have a very specific action on different species of bacteria. They believed that infections which were characterized by localized pro-

esses would be most successfully treated by local disinfection with a specific disinfectant.

Their studies had led them to investigate the various dyes particularly those of the acridine group. Ehrlich found that one of these, *acriflavine*, had a powerful lethal action on trypanosomes and Neufeld found that it was effective against the pneumococcus and the chicken cholera bacillus and that it was not inactivated in the presence of serum. They also investigated the triphenylmethane dyes but found them in general to be too highly irritating to the human tissues. In 1911 Hata made this wise remark: "The choice of methods of treatment, the size of dose or the avoidance of ill effects from the drug may require even more hard labor on the part of the clinicians than the originators of the drug used in its preparation."

Following the war the study of the dyes was taken up with avidity both in England and in Germany. Browning became one of the chief advocates of various dyes particularly for local use in the treatment of surgical infections and in the prophylaxis of wound infection but Fleming cautioned against their use because of the damage which resulted to the underlying tissues and the interference with the phagocytic function of the leukocytes. Nevertheless these dyes were widely used and in the course of the next few years *acriflavine*, *gentian violet* and *mercurochrome* achieved popularity and were credited with the cure of numerous cases of hemolytic streptococcus and *Staphylococcus aureus* septicemia. Hugh Young and his coworkers in Baltimore were the chief advocates of the intravenous injection of *mercurochrome* and of *gentian violet* in septicemia and local infections. Young compiled 680 cases which had been so treated with unusual success. Many laboratory studies were made which seemed to give a rational basis for dye therapy and the favorable clinical reports were legion. On the other hand other authors warned against too sanguine hopes from intravenous dye therapy. Some found no evidence of antibacterial action in the blood of animals injected with *mercurochrome* while others demonstrated damage to tissues and organs in autopsies on treated cases. Those who reported failures concluded

either that the treatment was ineffective or that it was directly harmful and hastened rather than prevented death. Many others maintained that the drugs became highly diluted when injected intravenously, had selective affinity for certain tissues and were thus diverted from their action on the bacteria.

These difficulties were not overcome by the intra-arterial injection of these drugs. The dyes thus injected and presumably suffused into the infected focus in a concentrated form had no favorable action on the infection but rather intensified or prolonged it and the dyes were picked up by the liver and kidneys where they invariably produced focal necrosis.

Gradually clinical evidence began to accumulate which tended to convince everyone that these dyes were both ineffective and dangerous and they have finally been abandoned.

In the meanwhile working on a different principle a chemical agent was found which was nontoxic to local tissues and to the body as a whole which would liberate oxygen so slowly that when topically applied to infected surfaces it would raise the oxidation-reduction potential of the surrounding tissues to such a degree that growth of organisms particularly those susceptible to peroxides would be prevented, their toxins inactivated and the anaerobes and microaerophiles would be promptly destroyed. This agent was *zinc peroxide* and its value was soon made manifest in the treatment of anaerobic infections and in the prevention of infection in wounds known to be or likely to be contaminated with anaerobic organisms. An important shortcoming of zinc peroxide is the fact that it can be used only as a topical agent in open wounds.

THE SULFONAMIDES

The search for a more effective and less harmful dye continued and in 1935 Domagk tentatively and cautiously presented his experience with a new azo dye which he called *Prontosil* and which he had found to be effective when given by mouth against many lethal doses of hemolytic streptococci injected into the peritoneal cavities of mice.

Domagk's results were not immediately followed up in Germany but Colebrook in England confirmed his results on animals and cautiously applied the drug to relieve distressing and

difficult problem of hemolytic streptococcal puerperal fever. Such cases in London as developed in the home or in other hospitals were isolated in Queen Charlotte's Hospital under Dr. Colebrook's care where he had the unusual opportunity of studying a large number. As his experience accumulated it was clearly demonstrated that he was able with the use of this new dye not only to lower the mortality of the disease significantly but in those cases which survived to minimize the intraperitoneal spread of the infection and shorten the period of illness. The use of the drug in the prophylaxis of this disease in cases showing evidence of antepartum, partum or postpartum contamination with the hemolytic streptococcus naturally followed and it was then cautiously applied by others to other types of hemolytic streptococcus infections both medical and surgical.³

Meanwhile certain French observers had demonstrated that the active element of the dye was a simple colorless chemical para amino benzene sulfonamide which was later given the simplified name *sulfanilamide*.

It was soon evident that this new drug would modify the course of various types of hemolytic streptococcus infections and if given in the early stages before there had been any breakdown of body tissues there was frequently a prompt resolution of the process. It was found that cases of hemolytic streptococcus peritonitis so often fatal could be brought under control promptly and hemolytic streptococcus meningitis almost invariably fatal could frequently be cured. It was not long before the drug was widely used by everyone—doctors, pharmacists and patients themselves for every type of infection without making any attempt to find the causative organism. One frequently heard doctors say "I didn't know what it was so I tried sulfanilamide."

It was then observed that many cases of unknown etiology fulfilled the response to sulfanilamide therapy and toxic manifestations began to be reported. When cultures were taken it was discovered that the sulfanilamide was effective in pneumococcal and non-hemolytic streptococcal or staphylococcal infections. With respect to the pneumococcus this was surprising because that organism usually produces a diffuse cellulitis of the

lung without a rapid breakdown of tissue. With the staphylococcal infections on the other hand the early breakdown of tissue was thought to be a major factor in the inadequacy of the drug to halt the process. Abscesses which formed during hemolytic streptococcus infections still required surgical drainage. The drug could often be demonstrated in the pus and frequently a culture of the pus would be reported sterile although organisms could be seen in the stained smear. If in such a case the drug was stopped positive cultures from the pus would reappear. In the cases of cellulitis with or without localization early cessation of the drug treatment would often result in an exacerbation of the process.

Mechanism of Action

It was not long before a large number of individuals in different laboratories proceeded to study the mechanism of action of the drug on various bacteria and the behavior of the drug in the body. The contributions of Marshall in the pharmacological study of sulfanilamide were outstanding. At the same time efforts were being made to find some derivative of the drug which would have a wider range of antibacterial action and less toxicity.

The well known antiseptics particularly the salts of mercury have a wide range of bactericidal action but they are protoplasmic poisons and are almost as potent against body tissue cells as against bacterial cells. Furthermore their bactericidal property is often inhibited by the presence of body fluids. The early antiseptic dyes were perhaps more specific but often had a predilection for certain tissues of the body and were toxic to these tissues as well as to the liver and kidney. Sulfanilamide however was found to be *bacteriostatic* rather than bactericidal, fairly specific in its action and highly effective in serum. In the test tube it could be depended upon to inhibit the growth of small numbers of hemolytic streptococci in concentrations which are reached in the blood when the drug is given by mouth usually 1 to 10 mg. per 100 cc. However this same concentration could not stop the growth of large numbers of organisms. Furthermore it is ac-

teristatic or bactericidal effect could be frustrated by the presence of peptones in the medium

It was obvious that some mechanism must be at work in the body other than a direct bactericidal action of the drug on the organisms. When it is remembered that in any infection of the body due to micro organisms there is a struggle going on between the offensive forces of the organism and the defensive mechanism of the body when drug therapy is being considered the reaction of all three of these factors upon each other must be carefully studied. The body may injure or destroy the bacterium the bacteria may injure or destroy the body. The drug may injure or destroy the bacteria or they may inactivate or destroy the drug. The drug may injure or destroy the body or be inactivated, eliminated or destroyed by the body. The ideal drug or antiseptic would be one which would destroy all of the organisms pathogenic for man and yet not injure the local tissues or the body as a whole. When these criteria were applied to sulfanilamide it was found that the drug has a bacteriostatic effect on certain species and small numbers of bacteria that small numbers do not inactivate the drug but large numbers do so. The drug does little if any damage to the local tissues but may cause severe toxic symptoms on the body as a whole. Normal tissues absorb the drug without altering it but *damaged tissue or pus inhibits the drug*.

The specific nature of this inhibition by pus or damaged tissue is not known but is thought to be due to the presence of peptones for in the test tube these split products of protein have been shown to definitely inhibit sulfonamide bacteriostasis. In the meanwhile a specific inhibitor of sulfanilamide was found in a relatively simple chemical compound—*para amino benzoic acid*. This drug is not very different in its chemical make up from sulfanilamide and at the same time is known to be utilized by bacteria in their growth process. It is possibly a constituent of all animal proteins.

In order to gain a foothold in the body tissues or multiply in culture media bacteria must utilize the nutrient elements in the immediate environment. This utilization is accomplished by the action of *enzymes*. These enzymes digest or change the nu

trient elements into simpler substances which can be absorbed and utilized by the bacterial cell. If the metabolism of the bacterial cells were the same as that of the tissue cells they could go on living like the body cells in a perfect symbiosis but bacterial cells have the habit in most instances of rapid multiplication and many of them excrete poisons or toxins which may be entirely incidental to their growth processes but which may destroy the tissue cells and phagocytes in the immediate environment. Anything which can prevent the utilization of the surrounding nutrient elements by the bacteria will prevent their multiplication. Para amino benzoic acid is a substance known to be one of the requirements for bacterial growth and its structural similarity to sulfanilamide has suggested that the latter may be taken up by the bacterial cell by mistake in the place of para amino benzoic acid. The bacterial cell then not being able to utilize the drug fails to multiply and either dies of its malnutrition or falls an easy prey to the phagocytic activity of the leukocytes. Thus the sulfonamide drugs do not directly kill bacteria but only interfere with their nutrition.

Other theories of sulfonamide action are based upon evidence of *anti enzyme activity*. One of these theories is built on the observation that the drug inactivates catalase which normally acts upon the hydrogen peroxide which is elaborated by the bacteria and which if free to act destroys them. One difficulty with this theory is the fact that some bacteria which do not form peroxide are susceptible to sulfonamides. One would expect that if this hypothesis were correct oxidizing agents would augment the action of the sulfonamide and there is some evidence that this is true. The oxidizing agents may however inactivate inhibitor of sulfonamide action and thereby augment the effectiveness of the drug.

The search for other derivatives of the sulfonamide group which might have a wider range of activity resulted in the discovery of *sulfapyridine* which is effective against the hemolytic streptococcus the pneumococcus the gonococcus and meningococcus and *sulfathiazole* which is active against these organisms and is also to a certain extent effective against the staphylococcus and the anaerobic clostridia. These two drugs

are more toxic than sulfanilamide due largely to the fact that the acetylated forms of sulfapyridine and sulfathiazole are considerably less soluble in the urine than the free drugs and often crystallize out in the tubules of the kidney thus blocking the outflow of urine. This has occasionally resulted in a fatal outcome. The acetylated form of sulfanilamide and sulfadiazine are more soluble and less likely to block the kidney though cases have been observed of anuria with sulfadiazine.

Sulfadiazine the latest derivative seems to have an even wider range of bacterial activity and at the same time seems to be less toxic than the others. It is less nauseating and therefore more acceptable to patients and interferes less with the intake of food. Experience with this drug has not been extensive enough as yet to determine its clear indications or its limitations.

The pharmacological study of these drugs has demonstrated that they are all rapidly absorbed from the gastrointestinal tract chiefly from the small intestine. When given by mouth peak levels are found in the blood within four hours except for sulfadiazine which reaches its height in six to eight hours. They pass through capillaries readily and reach concentrations in all body fluids similar to that in the blood.

For some reason not yet understood sulfathiazole does not penetrate the central nervous system as readily as the other drugs its concentration in the spinal fluid being only one half of that in the blood. The drugs may be found two to three times more concentrated in inflammatory exudates but their action is inhibited by these exudates.

Dosage

Fairly constant blood levels of sulfanilamide and sulfadiazine can be maintained by oral administration. It is more difficult with sulfapyridine and sulfathiazole. The level is modified considerably by the volume of urine flow and the efficiency of the kidneys.

With an intake of 500 cc. of fluid and a urine output of about 1000 cc. a sufficient and safe blood level of sulfanilamide may usually be maintained with an initial dose of 0.1

gm per kilogram of body weight and thereafter the same dose in twenty four hours divided into six parts one part being given every four hours. It is usually convenient to make the daily dose for persons of average weight 1 gm every four hours. This generally results in a blood level with sulfanilamide of 6 to 10 m μ per 100 cc. Levels as high as this with sulfapyridine or sulfathiazole may require *intravenous administration* of the sodium salts given slowly in 5 per cent solution. Sulfadiazine may be safely given in doses of 0.2 to 0.3 gm per kilogram of body weight and levels of 10 to 30 mg per 100 cc may be readily reached. This may then be maintained by lower doses because of the slower excretion of sulfadiazine.

When sulfanilamide is deposited on exposed tissues as a *powder* it is found to be readily soluble in the tissue fluids and may reach the concentration of 1500 mg per 100 cc of blood. It is readily absorbed and is all gone in two or three days. Sulfathiazole and sulfadiazine are much less soluble in local fluids reaching a level of not more than 100 m μ per 100 cc of blood and they are much more slowly absorbed. The latter drugs tend to produce more foreign body tissue reaction than sulfanilamide.

T R et

The toxic reactions of these drugs are sufficient to contra-indicate their indiscriminate use. Sometimes they develop promptly indicating an idiosyncrasy on the part of the patient. Usually however they appear in the second week of administration. *Sulfanilamide* frequently causes cyanosis and less frequently anorexia, nausea and vomiting, mental aberrations, depression and hallucinations. After five days fever may develop which has to be differentiated from a recurrent activity of the infection. The red cells may fall slowly or abruptly and occasionally there is a severe hemolytic anemia. The white cells also may drop rapidly and a true agranulocytosis may develop which may prove fatal if not observed promptly and if the drug is not immediately stopped. Hepatitis with jaundice is rare but when it does occur it is a serious toxic manifestation which may be prolonged for days.

or weeks. The toxic reactions usually disappear rapidly with a withdrawal of the drug but fever may continue for several days. If hepatitis develops recovery may be very slow indeed.

Sulfapyridine gives all of the toxic manifestations of sulfanilamide and besides extreme nausea and vomiting which often makes the patient rebel against taking the drug. *Sulfathiazole* and *sulfadiazine* have therefore largely replaced sulfapyridine and the latter may gradually drop out of use. Sulfathiazole is less nauseating but is more apt to cause a maculopapular skin rash or erythema nodosum. Sulfapyridine and sulfathiazole are chiefly dangerous because the acetylated forms of these two drugs are more or less insoluble and result in blockage of the kidneys as mentioned previously. It is a fact of considerable interest that apart from the renal complications severe toxic effects of sulfonamides occur very rarely among patients with active invasive infections.

Factor influencing the treatment with the Sulfonamides

Barring the toxic manifestations which occasionally occur and must be watched for in every case the successful use of these drugs depends upon a number of conditions which have been suggested by the preceding discussion. These may be listed as follows:

1. The concentration of the drug transported to and maintained in the area of infection.
2. The duration of the treatment.
3. The relative number of bacteria involved in the process.
4. The susceptibility of the causative organisms to the sulfonamide used.
5. The amount of tissue breakdown.
6. The ability of the body to remove or destroy the inhibited bacteria.

Adequate dosage over a long enough period of time is of considerable importance. Larger doses are now being used than in the beginning because they have been found to be tolerated in the majority of cases and if all of the toxic manifestations are watched for the drug can be decreased or stopped in time. Recurrent infection after the drug has been

stopped is frequent with certain organisms which are not very susceptible e.g. the staphylococcus. Not infrequently the presence of abscesses in the brain, in kidney or in bone has been masked by the drug and they may appear long after the drug has been stopped.

A good blood supply is of course of the greatest importance in the transportation of the drug to the site of infection. If there is already an abscess cavity with thrombosed blood vessels in the wall the drugs cannot be expected to get in in sufficient quantity to destroy the organisms and the necrotic tissue inactivates the drugs. Such localization of infection requires surgical intervention. The continued use of the drugs may then protect the periphery of the lesion and the body as a whole.

As the newer sulfonamides have been added the range of effectiveness has been gradually increased. Sulfadiazine appears to be effective against most of the types of bacteria which are susceptible to other drugs and to others besides. It is nevertheless important to determine as soon as possible by careful bacteriologic studies the etiologic agent in any infection and then use a medication known to be potent against the organism in question. If organisms are present which are not susceptible to any of these drugs other methods or medication must be employed. This applies particularly to the local treatment of anaerobic infections in which zinc peroxide may be more effective than any of the sulfonamides.

Surgical Infections

It must be remembered that surgical infections are distinguished from medical infections chiefly by the fact that they are local processes usually associated with a breakdown of tissue. The bacteria causing surgical infections are the pyogenic or necrotizing organisms.

Surgical infections also occur in operative wounds or in accidental wounds. It is true that infection frequently spreads from the original portal of entry to other parts of the body, but even then the organisms tend to produce local areas of necrosis. In staphylococcal infections particularly a suppurative thrombophlebitis in the neighborhood of the infection

may be a constant source of dissemination of organisms into the blood stream

When localized suppuration or necrosis takes place there must almost always be a surgical procedure and when there is an indication of thrombosed blood vessels they must be ligated if possible. If it is not possible to ligate such veins the use of heparin must be considered in order to prevent propagation of the infected thrombus. It has been well said that the sulfonamide drugs will often do what surgery will not do and vice versa surgery will do what the drugs cannot do. They must usually be used in conjunction. In traumatic wounds damaged tissue and foreign bodies must be removed as completely as possible before the drugs are applied.

It is possible that later experience with *war wounds* will prove that a compromise may be made and that with the use of the drugs a less radical operative procedure or a less thorough cleansing of the wound may be done successfully but this is not supported by any actual experience which we have had with these drugs. The greatest usefulness of the sulfonamides in military surgery will be in helping to prevent *contaminated* wounds from changing into *infected* wounds. There is no reason yet to predict that sulfonamide prophylaxis will permit safe primary closure of war wounds regardless of other circumstances. However a wound which has been treated early with a sulfonamide will probably remain in condition suitable for debridement for many hours. This will constitute a real advance because during World War I it was found that wounds more than twelve hours old after contaminating bacteria had started to multiply were poor subjects for debridement and usually become infected.

The current literature contains many articles reporting the use of these newer chemotherapeutic agents in the treatment of surgical infections. One is struck by the absence or the inadequacy of the bacteriologic studies in most of these reports as well as the absence of controls. It should be emphasized that the use of these drugs in some infections is still in the experimental stage and it is essential that the data presented be statistically significant. It is of the utmost importance to have a complete bacteriologic analysis of infections

treated with these drugs in order that we may be able to find out just what they are able to accomplish

During the past five years in the Presbyterian Hospital in New York and in the Hospital of the University of Pennsylvania in Philadelphia, the newer chemotherapeutic agents have been employed with steadily increasing frequency in surgical conditions. The largest groups numerically are postoperative pneumonia peritonitis peritoneal abscess cellulitis ulcerations of the skin and postoperative cystitis and prophylactically in resections of the bowel colostomies accidental wounds and burns. A number of cases which are illustrative of the method of treatment and the results obtained are appended herewith.

ILLUSTRATIVE CASES

Case 15 pp. at the Arthritis of Sternum I J. + A. Oct. 1940
with 5 bp. sterile Abscess of Clavicle I. S. D. A. G. S. L. f. t. h. a. l. The py.

A forty-four-year-old white male was admitted on August 7, 1940, on account of pain and swelling in the region of the right sternoclavicular joint. He had been eating heretofore with sulfathiazole in uncertain doses. She had a severe chill just before admission. Temperature 103.6 F, pulse 116, respiratory rate 8, white blood count 16,000.

Sulfathiazole was started at the rate of 4 gm. followed by 1 gram every four hours. On the following day the inflammation was explored and proved to be a suppurative arthritis of the sternoclavicular joint, associated with a hyperosteoarthritis of the clavicle. Blood culture was positive for Staphylococcus aureus (coagulase positive) and the same organism was recovered from the wound. Following general and drainage with sulfathiazole was continued at a dose of 1 gram every four hours. In ten days a blood culture at about 60 minutes per 100 cc. R. p. d. improvement followed and by the fourth day the temperature, pulse and respiratory rate were recorded.

The later record made and laboratory secondary results temperature which later proved to have been due at last to

W. D. B. D. D. I. S. R. d. f. th. p. lege. f. porting
Cases I II and III h. h. w. treat d. h. serv. h. f. f. sp. f. f.
th. U. r. s. v. f. P. s. l. Ph. l. d. l. ph. Th. m.
tre. d. h. S. r. m. al. Serv. f. th. P. esb. r. m. Hosp. al. N. w. Y. k.
City.

part to sulfathiazole intoxication as evidenced by the simultaneous appearance of a rash resembling erythema nodosum. Sulfathiazole was discontinued on the ninth postoperative day after the temperature reached 104.6° F and the pulse 110. The fever then disappeared. However four days later a second rise in temperature occurred which could not be attributed to the sulfonamide. On this occasion there were signs of recurrent infection and cellulitis in the wound apparently reactivated as a result of withdrawal of the sulfathiazole. Following revision of the drainage wound the patient's temperature again returned to normal. She was discharged on the thirty-ninth day with a wound which was still draining. Complete healing subsequently occurred following excision of a sequestrum.

CASE 11 Appendicitis with Perforation and Peritonitis. Postoperative Sulfanilamide Therapy. Result Good.

A seventeen-year-old high school boy came in on January 15, 1940, complaining of abdominal pain of eighteen hours' duration. Examination showed generalized abdominal tenderness, more marked on the right; acute rebound tenderness and rigidity of the muscles on the right side. Temperature 101.7° F, pulse 110, white blood count 18,000.

At operation through a McBurney incision under spinal anesthesia the preoperative diagnosis of appendicitis with perforation and peritonitis was confirmed. The appendix was in retrocecal position and a considerable amount of creamy green pus was present around a large perforation at the tip. Turbid fluid was aspirated from the peritoneal cavity. Parietal and visceral peritoneum in the exposed area was thickened, red and hyperemic. Appendectomy with drainage was performed. Aerobic culture showed *B. coli* and nonhemolytic streptococci.

After operation the pulse rate rose to 128 and temperature to 101.8° F. Peritonitis was definitely suppressed. Sulfanilamide therapy was started at once: the patient received 100 cc of 10 per cent solution of the drug in saline every six hours for doses, followed by 150 cc every six hours for six doses. Temperature and pulse dropped slightly but did not reach normal level on the third postoperative day. By this time peritonitis had returned actively; the patient was passing gas and was free of complaints. He was quite exsiccated during the course of sulfanilamide therapy but this was disregarded. Sulfanilamide continued for ten days.

The drains were all removed by the seventh day and the wound healed without complications. Patient was discharged on January 31, 1940.

(Note: At the present time it is our practice to deposit 4 to 6 gm of crystalline sulfanilamide in the peritoneal cavity and abdominal wound in cases of this type. Further doses of sulfanilamide solution are administered according to the plan followed in the above case.)

Case III Sp. d. g. Cell. l. t. s. f. Thigh. d. G. o. f. P. b. ble. Str. pt. c. al. O. g. Cure with Sulfanilamide

A woman aged twenty-seven years who had been nursing a patient with a severe streptococcal pharyngitis developed a diffuse and spreading cellulitis of the left upper thigh and groin around a trivial scratch. No open lesion from which a culture could be taken was present. Fever rose to 103° F. with a chill and prostration was marked. Sulfanilamide was started on the second day. Twenty-four hours later it was apparent that no further spread had taken place. On the third day the temperature was normal and the signs of the cellulitis had virtually disappeared. No localized suppuration occurred. Blood cultures remained negative. The initial dose of sulfanilamide was 4 grams followed by 1 gram every four hours until the lesion was definitely under control. Thereafter the dose was reduced slowly and progressively and finally discontinued on the seventh day. Two transfusions of 500 cc of whole blood were administered in order to correct a mild anemia.

C. IV Ac. t. Hem. l. y. c. St. pt. c. al. Ul. a. B. s. t. s. R. ol. t. n. F. ll. w. g. S. g. ry. d. S. H. l. m. d. Th. apy

A plumber formerly a member of the American Legion had pictured the palm of his right hand with a nail or a sharp forty-cent hole before dinner. Six hours after the injury the hand began to pain and swell and shortly thereafter the hand swelled so much that on examination the puncture hole was found just proximal to the first transverse flexor crease of the palm over the tendon of the fourth finger. It appeared to be a deep, clean, circular purulent exudate. There was swelling over the ulnar bursa but not over the little finger. At operation it was found that the picture wound had entered the distal portion of the flexor digitorum profundus but did not extend up into the first finger. The connection with the radial bursa. It did not extend up the arm.

wrist. The puncture wound was excised and the ulnar bursa opened in the palm to the radial side of the hypothenar muscles and above the wrist at the ulnar margin of the pronator quadratus.

The culture yielded a hemolytic streptococcus. The patient was given 5.4 gm of sulfanilamide by mouth on the first day, 4.5 gm on the second and third days and 3.4 gm on the fourth day. His temperature was 100.4° F on admission and steadily mounted to 103.6° F on the fourth day. The urine revealed sugar. The blood sugar was 198 mg per 100 cc but was brought down to normal with diet and insulin. The hand promptly and steadily improved. In the face of the rising temperature a diagnosis of drug fever was made and the drug was stopped. Still the fever mounted—104° F on the fifth day, 104.8° F on the sixth day and 106° F on the seventh day. On this day the sulfanilamide blood level was 2.5 m per 100 cc. The patient was placed in an oxygen tent. His temperature then fell by crisis and was normal two days later and stayed normal thereafter. The hand improved steadily and the function was completely restored. The wound was healed on the sixteenth day.

The case illustrates the rapid resolution of an acute hemolytic streptococcal ulnar bursitis of forty-eight hours duration following adequate surgery and four days of moderate dosage with sulfanilamide. In spite of that the patient developed a severe drug fever which continued to mount to 106° F two days after the drug was stopped. It fell to normal in the next forty-eight hours after the patient had been placed in an oxygen tent.

CASE 11. VELY Diffuse Peritonitis Following Perforation of Appendix. Treated with Sulfonamide Locally at Operation and Systemically.

J. S., a girl fourteen years of age, had had a nineteen-hour history of epigastric pain shifting to the right lower quadrant. On examination the right rectus muscle was found to be in pain with direct and rebound tenderness over the right lower quadrant. At operation the appendix was found to be markedly inflamed, covered with fibrin and perforated near its middle. There was a large quantity of turbid fluid free in the peritoneal cavity. There was no evidence of localization. The appendix was removed and the stump ligated. Five gm of sulfanilamide were sprinkled in the peritoneal cavity, particularly around the appen-

The drains were all removed by the seventh day and the wound healed without complications. Patient was discharged on January 31, 1940.

(Note: At the present time it is our practice to deposit 4 to 6 gm. of crystalline sulfanilamide in the peritoneal cavity and abdominal wound in cases of this type. Further doses of sulfanilamide solution are administered according to the plan followed in the above case.)

C III Sp. d. g. Cell. It. f. Th. gh. d. G. f. P. babl. St. pto.
ccal. O. g. Cure with S. lf. lam. d.

A woman aged twenty-seven years who had been nursing a patient with a severe streptococcal pharyngitis developed a diffuse and spreading cellulitis of the left upper thigh and groin around a triangular scrotal wound. No open lesions from which a culture could be taken. Temperature rose to 103°F. with a chill, and prostration. Sulfanilamide was started on the second day. Twenty-four hours later it was apparent that no further spread had taken place. On the third day the temperature was normal and the signs of the cellulitis had virtually disappeared. No localized suppuration occurred. Blood cultures remained negative. The initial dosage of sulfanilamide was 4 grams followed by 1 gram every four hours until the lesion was definitely under control. Thereafter the dose was reduced slowly and progressively until finally discontinued on the seventh day. Two transfusions of 500 cc. of whole blood each were administered in order to correct mild anemia.

C IV A. t. Hem. lyt. St. pto. l. UI. B. sts. Re. l. t.
F. ll. w. g. S. g. ry. d. S. lf. l. m. d. Th. py.

J. M., a plumber forty-six years of age, had punctured the palm of his right hand with a nail on the forty-eighth hour before admission. Six hours after the injury the hand became painful and swollen, and he felt the heat of his hand. On examination the puncture hole was found just proximal to the first transverse flexion crease of the palm, rather than at the fourth finger. It was found to be surrounded by some thin purulent exudate. The creases of the ulnar bursa but not of the little finger. At operation it was found that the puncture wound had entered the distal portion of the ulnar bursa. The bursa did not extend up into the little finger. It was not connected with the radial bursa. It did not extend up beyond the

The patient was put in an oxygen tent and the administration of sulfathiazole was started 1 gm every four hours. This was continued for five days. The blood levels of sulfathiazole were 1 m per 100 cc on the first day after administration and 4 mg on the third day. The temperature came down by lysis and the pneumonia promptly cleared. After the seventh day the convalescence was smooth and the patient left the hospital on the nineteenth day.

This case illustrates a typical case of postoperative pneumonia involving at least three lobes with pneumococcus type VI. The disease responded promptly to the administration of sulfathiazole which was well tolerated.

Case VII. Chronic Brown infection of Buttocks and Adjacent Region. Prompt Response to Excisional Zinc Peroxide after Failure of Conservative Methods. Since made Theopy

P. T., an Italian truck driver aged forty-four years, had a history of infection of fourteen years' duration. Starting as an abscess of the buttocks, an extensive undermining burrowing infection had developed and had slowly spread completely over both buttocks and scrotal region over the posterior left thigh around the anus into the perineum over the back of the scrotum and into both groins (Fig. 17A). In the early years the treatment had been repeated incisions and countless varieties of antiseptics and ointments. In recent years numerous attempts had been made to control the infection with sulfanilamide and sulfathiazole without success.

At operation the infected area was completely excised down to the muscles and deep fascia. The wound was then flooded with a creamy suspension of zinc peroxide and overlaid with a thin layer of absorbent cotton soaked in the same suspension. This in turn was covered with a thick layer of absorbent cotton soaked in water and then sealed with a double layer of fine meshed gauze impregnated with aseline.

The culture revealed the expected microaerophilic hemolytic streptococcus, an anaerobic nonhemolytic streptococcus, Staphylococcus aureus (nonhemolytic), B. proteus and B. coli. With daily zinc peroxide dressings granulations developed rapidly and new skin began to grow in from the margin. The patient was ready for skin grafting on the sixteenth day. About 450 small deep grafts were removed from the upper back and

dix stump. A soft rubber tube was placed down toward the site of the appendix. The peritoneum and muscles were closed loosely around the drain and 5 gm. of sulfanilamide were sprinkled the wound surfaces. The skin was left open.

The culture of the peritoneal fluid yielded *B. coli* and a non-hemolytic aerobic streptococcus. Twelve hours after operation the sulfanilamide level was 4 mg. per 100 cc. of blood. The temperature on admission had been 103° F. and it fell by 1½°. An attempt was made to pass a Miller Abbott tube but it would not go beyond the pylorus. On the day after operation 4 gm. of sodium sulfadiazine were given slowly intravenously. For the next five days sulfadiazine was given by mouth 1 gm. every four hours, and for four more days every six hours. The level per 100 cc. of blood ranged as follows: second day 4 mg., fifth day 10 mg., seventh day 9 mg., tenth day 11 mg. On the tenth day the temperature began to rise and as there were no local signs it was thought to be a drug fever. The drug as such was stopped. Fever continued and reached 103° F. Then a tetracycline was felt in the right lower quadrant and in the pelvis. An additional drug was used. The temperature gradually fell to normal on the twenty-first day.

The case illustrates a relatively early diffuse peritonitis following a perforation of the appendix in which the patient was given sulfanilamide locally and sulfadiazine generally. The peritoneum took care of the infection but there was some localization in the pelvis which cleared spontaneously after being observed for ten days.

Cs. VI Typ. I Pst p. t e P m P mpt R p f
S If th I Th py

I. C. a woman thirty years of age came to the hospital for the removal of a chronically inflamed gallbladder containing stones. Her temperature had been normal before operation. On the day after operation the temperature again rose to 101° F. In the evening of that day respiration increased to 30 per minute and during the night typical symptoms of postoperative pneumonia developed. The temperature rose to 104.4° F., pulse 130 and respiration 38. Sputum revealed type VI pneumococcus. The minimum reflex film revealed a localized right middle lobe and posterior basal segment of the right lower lobe.

cure the disease with conservative surgery and with the sulfonamides had failed. It responded promptly to excision and zinc peroxide. After skin grafting a comparison was made of the healing properties of zinc peroxide and sulfadiazine.

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placed on the granulating surface held in place with a snare layer of coarse meshed gauze sealed to the skin margins with collodion and covered with wet saline compresses. The zinc peroxide was renewed after twenty-four hours, and then changed daily. On the sixth day after the skin grafting the grafts being well established and the essential organization on the opportunity offered itself to compare the wound healing of the two sides, one continuing zinc peroxide and the other using sulfadiazine powder.



A



B

Fig. 127—A. Undermining of the cheek and removal of the infected tissue. B. Completion of the healing process after the application of the zinc peroxide dressing.

The latter was spread on the powder in a thin layer like a frost. This was covered with fine meshed gauze wet with sterile distilled water and then secured in the manner as the zinc peroxide dressing. Final healing was accomplished first on the zinc peroxide side (Fig. 127A & B) but generalizations cannot be made on the basis of relatively minor experience. Further comparisons of this kind should be of value.

The case illustrates a serious type of chronic infection similar to those previously reported. Numerous attempts to

cure the disease with conservative surgery and with the sulfonamides had failed. It responded promptly to excision and zinc peroxide. After skin grafting a comparison was made of the healing properties of zinc peroxide and sulfadiazine.

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IMMUNOLOGICAL ASPECTS OF SURGICAL INFECTIONS

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IMMUNOLOGY may be considered one of the basic sciences essential to the art of surgery. An understanding of the mechanism of bacterial infection is necessary for intelligent interference in the chain of events endangering an infected host. It is perhaps too seldom realized that the student of immunology or resistance to infection is as much concerned with the principles of asepsis and the technic of wound repair as with chemotherapy and serotherapy. This broader concept of the scope of immunology is presented to emphasize the necessity of a proper perspective in the evaluation of new procedures. Chemotherapy and serotherapy do not constitute a surgical specialty, but a well trained surgeon may require an intimate knowledge of such therapy in the pursuit of a special interest in surgical infections.

BASIC PRINCIPLES OF IMMUNITY

The problems presented by any given surgical infection are largely dependent upon the special attributes of the infecting organism or group of organisms. It is possible to define these reactions in broad terms only, but such definition has a practical value for purposes of discussion.

1. The capacity of bacteria to invade tissues.
2. The capacity of tissue to react to the local presence of bacteria.
3. The production of exotoxins or extracellular poisons by bacteria.
4. The systemic toxic effects due to component substances of bacterial bodies or endotoxins.

Each of the above subjects is worthy of more detailed consideration

The Capacity of Bacteria to Inhabit Tissues

The terms *virulent* and *pathogenic* are equivalent and imply a capacity of bacteria to survive and multiply within the tissues of a host. This property is to be distinguished from *invasiveness* which refers to the ability of micro organisms to spread through the tissues and body fluids. *Pathogenicity* or *virulence* may depend upon this factor of *invasiveness*, or upon an ability to produce a poisonous exotoxin or upon a combination of *invasiveness* and *toxigenicity*.

In the early days of morphologic bacteriology there was strong tendency to regard *capsule formation* as essential to the attribute of *invasiveness*. It was reasoned that such a capsule constituted a protective coating which was resistant to the destructive action of the cells and body fluids. This hypothesis still holds true in part but more recent knowledge has modified the basic conception. *Virulence* is definitely correlated with capsule formation in the case of the pneumococcus and the anthrax bacillus but both *virulent* and *avirulent* forms of the hemolytic streptococcus may be encapsulated. The protective function of the capsule is conditioned by the presence in the capsule of some chemical substance for which no reactive antibody exists in the serum of the host. Pertinent to this discussion is the established knowledge that many bacterial forms share common substances in their somatic constitution and differ chiefly in regard to the chemical constitution of the capsule. Hence the immune serum capable of promoting *agglutination*, *lysis* or *phagocytosis* must be type specific and capable of reacting with the particular substance which constitutes the protective coating of the bacterial body. Such sera are known as *antibacterial sera*. In the case of *gram positive* organisms the primary function of such sera is the promotion of *phagocytosis* and *subsequent intracellular digestion* of the bacteria. *Antibacterial sera* against *gram negative* bacteria produce both *bacteriolysis* and *phagocytosis* but there is reason to believe that *phagocytosis* is not constantly

associated with the subsequent intracellular digestion of ingested gram negative bacilli

The demonstration that avirulent bacteria might possess capsules has done much to discount the point of view that correlated invasiveness entirely with encapsulation. As accessory factors in invasiveness attention has been focused upon *leukocidin* and *spreading factors*. Leukocidin is a true bacterial exotoxin active against phagocytic cells and effective in preventing phagocytosis. The fact that antileukocidin sera have not strikingly influenced the clinical course of infections does not invalidate the theory that leukocidin may enhance invasiveness. Recently a new conception of the old aggression theory has been made possible by the recognition of the production of spreading factors by certain bacterial species. It is now suggested that such factors are mucolysins capable of reducing the viscosity of intercellular mucins by a process of rapid depolymerization of the mucopolysaccharide. This highly attractive explanation of the method of bacterial penetration of tissues is not as yet solidly substantiated but it is based on much fact and little fancy.

An understanding of this conception of bacterial invasiveness is necessary for the proper interpretation of cellulitis and lymphangitis and the bacteremia which accompanies this pattern of infection.

2. The Concept of Tissue Resistance to the Local Infection

The science of immunity has developed largely through a study of the circulating humoral antibodies and their effect upon systemic resistance. Emphasis upon this type of generalized resistance to infection has overshadowed conceptions of a local tissue immunity. Many workers have felt that it might be possible for certain cells or tissues to acquire resistance to bacteria independently of any known immunologic mechanism. Critical analysis of experiments attempting to prove the existence of a previously unrecognized type of local immunity still allows the alternative conception that immune bodies are concentrated in greater quantity in areas directly exposed to bacteria.

The surgical course of a simple abscess which heals after a discharge of pus suggests that healing is correlated with an *increased tissue resistance*. The factors concerned have been extensively studied. Menkin's observations upon the process of *inflammatory fixation* have emphasized an obstruction of the lymphatic pathways by a deposition of fibrin. Early in the inflammatory response there is vasodilation and increased capillary permeability but this is followed by vascular thrombosis in and around a central zone of necrosis. The obstruction of both lymphatic and vascular capillaries partially exteriorizes the area of bacterial infection from the rest of the body. In the case of the abscess devitalized tissue is cast out as slough or pus and the defect is repaired by adjacent unaffected cells.

It is obviously impossible to completely define the mechanism of so complex a reaction as the inflammatory response but some of the important factors have been studied. A substance has been isolated from the staphylococcus which is a specific incitant of inflammatory fixation. It is also clear that cellular reactions may be conditioned for abnormal response by previous exposure to bacterial proteins and metabolites as a consequence of bacterial allergy. An active immunity is associated with an accelerated defense against invading bacteria. It is generally agreed that all these factors are important in conditioning the inflammatory response but they fail to confirm the existence of some incompletely understood process of local immunity. However the known facts do not disprove the existence of enhanced cellular resistance to infection and new techniques of experimental analysis may change present conceptions.

Relatively little is known about the *effect of resistance within tissues* upon bacteria. Under certain conditions viable and fully virulent bacteria may persist indefinitely in certain tissues or organs without any demonstrable local reaction. On the other hand, attenuation of virulence and alteration of cultural characteristics may occur over a relatively brief period of time.

The *necrotizing action* of bacteria upon tissue may be influenced by allergic immunity and the inflammatory response in general. It is also probable that more severe necrosis is pro-

duced by certain polymicrobial infections exemplified clinically by lung abscesses peritonitis and gas gangrene. Repeated studies upon this problem of bacterial synergism have constantly demonstrated an increased necrotizing effect but have failed to demonstrate that bacteria growing together produce any new toxin not produced by some one of the organisms.

An understanding of the mechanism of inflammatory fixation is necessary for definition of the type of bacteremia which arises as a complication of the suppurative process. Such bacteremias are dependent upon an intravascular focus of infection and foci may exist as thrombophlebitis or endocarditis.

3 The Production of Bacterial Exotoxins

Exotoxins are best defined by a review of their biological characteristics. They represent cytotoxic substances given off by the bacteria during a period of active growth and metabolism. There is usually a definite but variable pharmacologic action and an enzyme-like quality of reacting in minute quantity with a tremendous volume of sensitive tissue. The hemolysins and leukocidins are of greatest interest to the surgeon.

Bacterial *hemolysins* have a tissue affinity comparable to that of alkaloids. The presence of lipid in tissues seems to determine vulnerability to hemolysins but it has not been settled whether this is due to a solubility of the exotoxins in lipoids or to an altered solubility of other cellular constituents in the presence of such lipoids. The importance of the work on lipoids is that it indicates the susceptibility of red blood cells, nerve tissues and suprarenal glands to hemolysins.

Bacterial *leukocidins* have a strong affinity for the cells of the granulocytic series and are effective depressants of phagocytosis. In vivo observations upon the greater phagocytic activity of the mononuclear phagocytes may find a partial explanation in the lesser susceptibility of these cells to the leukocidin of a given bacterial type.

The neutralization of bacterial exotoxins by antitoxins is accomplished in accordance with a rule of multiple propor-

(The following is a list of the authors of the papers in this volume, arranged alphabetically by last name.)

tions. Regardless of the total quantity of the exotoxin it should be possible to find a comparable quantity of antitoxin capable of neutralizing the toxic action. It should be remembered that antitoxic therapy can only neutralize the free toxin and not that already fixed to the susceptible tissue. It does not immediately repair the damage that has been done prior to the time of giving antitoxin.

4. The Effect of Bacterial Endotoxins

Endotoxins are poisonous substances derived from the constituents of the bacterial body. They are released only as the result of disintegration or lysis of the bacteria. The endotoxins of gram negative bacilli have been most intensively studied and the organisms of the colon dysentery group have been shown to contain a toxic glycolipid. Other less toxic substances are undoubtedly protein in nature. The endotoxins appear to be distinct from the less well defined group of bacterial derivatives known as Schwartzman antigens and concerned with eliciting Schwartzman's reaction of bacterial hypersensitivity.

Immune bodies to these endotoxins are of a different order of efficiency as compared with anti exotoxins. Neutralization by any amount of anti endotoxin is limited to a few minimal lethal doses of the endotoxin and beyond this limitation the antitoxin is completely ineffective. Another approach to the problem has been outlined by the observation that the glycolipid endotoxin of gram negative bacilli may be relatively easily dissociated into nontoxic carbohydrate and lipid components. Maximum toxicity depends upon the integrity of the complex and any dissociating factor would theoretically diminish this toxicity. It is highly probable that recovery from the toxemia of appendiceal peritonitis is associated with some biologically active process which destroys the integrity of the glycolipid complex of the colon bacillus.

The action of endotoxins within the body is probably restricted to a necrotizing effect which is more evident locally and less marked systemically. Knowledge of the action of endotoxins is imperfect but new information is accumulating rapidly.

RESISTANCE TO SPECIFIC INFECTIONS

The clinical pattern of any given infection is largely dictated by the biological attributes of the etiologic organism and the variable immunity of the host. Specific therapy is directed as much by the clinical characteristics of an infection as by the laboratory diagnosis. Immunological procedures have come to play so important a role in laboratory and clinical diagnosis and in the regulation of therapy that it is pertinent to summarize some of the new information here.

Staphylococci

There are several criteria of virulence for the staphylococci as a group. Almost without exception the aureus strains are virulent but difficulty may arise in segregating avirulent from fully virulent albus strains. The production of hemolysis on a blood agar plate is of no significance but the production in broth cultures of a soluble hemolysin capable of destroying rabbit red blood cells is significant. Positive mannitol fermentation is fairly well correlated with virulence but the production of *staphylocoagulase* is probably the single most reliable test for pathogenicity. This coagulae has the power of inducing clot formation in oxalated or heparinized plasma but has no known role in the production of the inflammatory lesion.

Numerous researches have attempted to classify staphylococci on the basis of a *common chemical constituent*. Specific carbohydrates (Julianelle) and proteins (Verwey) have been demonstrated with the precipitation technique and chemically undefined type specific substances have been identified by the agglutination technique (Cowan). The most clearly established fact in these studies is that staphylococci share many common constituent substances. Such methods of classifying the staphylococci may have value in an epidemiological survey but are not important surgically at the moment.

The *exotoxins* of the staphylococcus include a number of hemolysins, a dermonecrotizing toxin, an intravenous lethal toxin and a leukocidin. The activity of all of these toxins is demonstrable in laboratory animals but the leukocidin is the only exotoxin which is clearly active in human infections. It is likely that the locally necrotizing action of staphylococci

far exceeds in clinical importance any poisoning by the exotoxins. Hence antitoxin therapy in human infections is validated only by inference from animal observations which have no clear human counterpart.

Antibacterial immunity to the staphylococcus is not yet defined. Foreign protein injections and shock reactions appear to modify the course of staphylococcal infections by a mechanism which lacks immunological specificity. Such nonspecific enhancement of resistance to infection has long been recognized and should be recalled in the interpretation of clinical reports upon the use of antitoxin, antibacterial sera and bacteriophage.

Bacteriologists and pathologists have long held that staphylococcal bacteremia arose from foci of intravascular infection. This point of view is rapidly gaining clinical acceptance.

Streptococci

For almost forty years streptococci have been differentiated on the basis of their effect upon red blood cells. Many of these original conceptions are being overthrown by the serological classification recently established by Lancefield. On the basis of a common chemical constituent the streptococci are now classified into groups A through M and such groups include hemolytic, green and nonhemolytic dissociants. Some strains produce green hemolysis on aerobic culture and beta hemolysis on anaerobic culture.

The group A strains comprise about 95 per cent of the serious streptococcal infections of human beings. True beta hemolysis is produced by most of these strains but green varieties are not uncommon. Completely nonhemolytic strains are apparently rare. Group A strains may be subdivided into types by Griffith's agglutination technique but the antibody responsible for agglutination is not a protective antibody. In most instances the strains of a given agglutinative type share a common protective antibacterial antibody, but this is not always true. Specific agglutinating sera are easily produced in animals but protective antibacterial sera are not readily secured by animal immunization. At the moment Griffith's agglutination classification is of importance in epidemiological studies.

but phagocytic or bactericidal techniques are necessary to evaluate antibacterial immunity. The only source of therapeutic antibacterial sera is human blood possessing the desired antibody. In a given community streptococcal infection tends to be limited to a few bacterial types although the prevalent types may vary from time to time. Several years experience with *immune transfusions* for streptococcal infection have demonstrated the value of human serum containing type specific antibodies for a given streptococcus. Immune donors can usually be found in a ratio of 1 out of 5 or 10 tested provided the donors come from the same community as the patient.

Groups B, C, D, F, G and H may also cause human infections. There is increasing evidence that the enterococci are frequently nonhemolytic dissociants of the group D although some of the enterococci are clearly heterologous. The group D organisms are apparently resistant to sulfonamide therapy.

The *erythrogenic* or *rash producing toxin* formed by group A strains is the most important exotoxin of the streptococci. Hemolysins, fibrinolysins and leukocidins are also formed but it is impossible to evaluate their clinical importance. The surgical infections requiring scarlet fever antitoxin are infrequent but such therapy may be useful in gangrenous erysipelas or surgical scarlet fever. Convalescent human serum gives fewer reactions than the more potent animal antitoxin. Recent methods of purification of animal antisera have done much to reduce the incidence of severe serum reactions.

T + 5

There are a number of different serological types of tetanus bacilli but all produce a similar tetanus toxin. Recent investigation strongly supports Abel's contention that tetanus toxin is absorbed from the site of infection by the lymphatics and blood vessels and is carried to the central nervous system by the blood. Nerve cells have a strong affinity for tetanus toxin. Antitoxin is not effective in the neutralization of the toxin after the toxin nerve cell complex has become established. This has given rise to the thought that fixation of toxin by the

nerve cell might produce a new toxic substance not neutralized by antitoxin. Attempts to produce an immune serum to neutralize such a new toxic substance have not been successful. It is a curious fact that in spite of the strong affinity between tetanus toxin and nerve cells recovery from tetanus leaves no sequelae in the way of permanent neurological disorders.

There can be no doubt that *prophylactic* tetanus antitoxin is clinically effective. Such tetanus as occurs after the use of prophylactic antitoxin has a prolonged incubation period and is often local instead of generalized tetanus.

The use of antitoxin for the *treatment* of established tetanus is mandatory on the basis of animal experiments but clinical statistics indicate that it is of limited value. This fact has led to the intrathecal use of the antitoxin as a more direct method of treatment. Clinical experience with intrathecal antitoxin is unfavorable and it is known that any foreign serum incites a inflammatory reaction in the subarachnoid space. At the moment there is little justification for the administration of more than 100 000 units of antitoxin to any one patient. This may be given locally around the wound intravenously and intramuscularly. Increasing attention is directed to the *symptomatic treatment* of tetanus along the lines of sedation and maintenance of caloric intake after surgical excision of the infected wound.

Active immunization with *tetanus toxoid* appears to be the most hopeful method of attacking the problem of tetanus. There is every indication that great success will attend this method.

G s G g n

Gas gangrene is always an infection with more than one bacterial species. There are two main divisions on an etiological basis: (1) anaerobic putrefactive nonhemolytic streptococcal and (2) clostridial.

There are no known therapeutic sera for the treatment of the anaerobic nonhemolytic streptococcal infections.

Various clostridia are involved in the causation of clinical gas gangrene with true toxemia. *Clostridium perfringens* (wel

chu) *Cl* septique *Cl* oedematiens (novyi) and *Cl* oedema toides (sordellii) are the most frequent cause of serious gas infections. *Clostridium perfringens* and *Cl* septique infrequently and only terminally invade the blood stream. *Clostridium oedematiens* is almost purely toxigenic. Of lesser importance as pathogens are *Cl* fallax *Cl* lentoputrescens (putrificus) and *Cl* histolyticum although the latter may produce an extraordinarily potent toxin capable of digesting living tissue. *Clostridium bifermentans* and *Cl* sporogenes often contribute to the local tissue necrosis and are frequently responsible for the foul odor of gas infection. *Clostridium sporogenes* produces a substance which inactivates the toxins of *Cl* oedematiens and *Cl* septique but does not affect the toxin of *Cl* perfringens. Living clostridia of the sporogenes type definitely enhance the virulence of *Cl* perfringens and the two organisms together produce a putrid gangrene.

Classical emphysematous gas gangrene is produced when *Cl* perfringens or *Cl* septique is the predominant organism. Predominance of *Cl* oedematiens leads to a clinical lesion with massive edema and little or no crepitus. This clinical picture is not completely reliable for the identification of the etiological bacteria and serum therapy must be employed on a polyvalent or shot gun basis. Potent antitoxins are available for *Cl* perfringens *Cl* oedematiens and *Cl* septique but the most practical sera for general use are the polyvalent sera which may be used before the specific cause of the gas gangrene in any given case can be identified. As soon as identification has been made the specific antitoxin should be employed. Experimentally effective antibacterial sera have been produced but there are so many strains of anaerobes producing similar toxins that it is impractical at the moment to attempt specific antibacterial serotherapy.

Authority for the routine use of prophylactic doses of gas gangrene antitoxins arises chiefly from animal experiments and a few scattered clinical reports. Decision to use prophylactic sera is based upon injury to muscle and the circumstances under which the injury was sustained. It should be remembered that muscle tissue may permit the growth of

anaerobes as a result of direct crushing injury or as a result of diminished blood supply from arterial laceration or shock.

The use of antitoxin in the therapy of established as gangrene should supplement surgical excision of the involved muscle or muscle groups and chemotherapy. Four to six therapeutic doses should be given initially and supplemented with two to four such doses every four to eight hours until the toxemia is controlled.

The preparation of gas gangrene *toxoids* is still in an experimental phase. Satisfactory antitoxin production occurs in animals with *Cl. perfringens* toxoid but there must be much more investigation before such a product can be used in man to replace prophylactic antitoxin.

Bacteroides and Fusobacteria

The great group of anaerobic nonspore forming gram negative bacilli is constantly incriminated as causative in a wide group of diseases such as acute appendicitis, lung abscess and chronic ulcerative colitis. There is little basis for the distinction indicated by the generic titles of these bacilli. Differentiation is on a morphological basis: bacilli with rounded ends are *Bacteroides* and those with pointed ends are *Fusobacteria*.

Infection with these organisms is characterized by intense local necrosis and similar necrosis may be produced experimentally with dead bacteria. There are suggestions that the injection of such bacteria may produce a state of inanition and cachexia followed by death at an appreciable interval after the original injection. These findings indicate that the *Bacteroides* and *Fusobacteria* contain a powerful endotoxin. Any report of the presence of such an organism should be interpreted from this point of view.

COMMENT

Increasing knowledge in the field of immunology is dictating a distinct trend in the management of surgical infections. Accuracy of bacteriological diagnosis is paramount and this predicates aerobic and anaerobic cultures of excised tissues and exudates. Sulfonamide therapy is primarily effective in the control of many bacterial species. Antitoxin therapy neutral

izes the powerful exotoxins which diffuse into the systemic circulation from the focus of infection. In other words it is now possible to control the systemic complications of surgical infections and emphasis shifts from the systemic effects to the local inflammatory process.

With the added protection of immunotherapy and chemotherapy an increasing surgical attack is being made earlier upon local foci of infection. This attack includes not only the drainage of pus but the excision of inflammatory foci and the ligation of tributary veins. Recognition of the importance of this combined immunological and surgical approach to the management of infections is in itself a justification of the statement that surgeons must be as competent as internists in the use of serotherapy and chemotherapy.

THE INDUSTRIAL BACK PROBLEM

IRVIN BALENSWEIG M D F A C S †

*Ability to estimate and eliminate the extent to which
 psychic factor enter a routine method of examination
 of the patient skill in interpreting the findings of the
 examination acquired by clinical experience and an
 tonic knowledge are the essential prerequisites in in-
 dustrial medicine and surgery*

—Osgood and Allison

In the quotation above Osgood and Allison have placed first the psychic factors in back injuries in industry this is significant for these play a major role Next to be considered is the method of examination for it is only by following a definite routine that all essential details can be noted and carefully recorded In this routine is included a detailed history a detailed physical examination followed by roentgen studies a summation of both the positive and negative findings and lastly a conclusion The conclusion should state the causal relationship the present percentage disability and the probable duration of disability

THE PSYCHIC FACTORS

The psychic element is present not only in the patient but also in the make up of the examining physician particularly if the examiner has had the patient referred to him by a company The examining physician must always try to eliminate

F m h D p r t m f S g y C ll Um rs v d h N
 v k H p al (S rv f D G g J H)
 † A c Cl n al P fes f Orth p d S g r v C ll U
 ty M d l Coll g A an v tng Orth p d S r N Y k
 H p l
 † F r d l f Orth p d S g r v G l M d d
 S re 1931 B p m f Th M m ll Comp N Y k

bias when evaluating the injury otherwise he is apt to consider the patient a malingerer or a willful exaggerator even before completing his examination. This tendency is an extremely unfortunate one yet it must be admitted that all of us are prone to make up our minds too quickly in that direction. It is least prevalent in those physicians who examine both for and against companies because they see both sides of the story and are better able to cope with the situation.

THE HISTORY AND LEADING QUESTIONS

Concerning the history taking I personally find it best to have the secretary obtain from the injured a detailed story of the accident and the sequence of events that took place up to the time of examination. I find that the patient is apt to be more fluent and is not as much on his guard as when the history is taken by the physician himself. The history can then be quickly reviewed by the physician and from this point on direct pertinent questions can be asked and the answers recorded.

Leading questions should cover the following points:

1 *The past history relative to previous accidents or operations*

Loss or gain of weight

3 *Change of occupation*

4 *The nature of the pain* Is it dull or sharp, radiating, continuous or affected by weather changes? It is important to remember that the arthritic patient suffers pain prior to the onset of weather changes and is relieved during the change whereas the patient suffering from an injury may complain of pain at all times and may feel worse during the change in the weather. It is important to determine what, if anything, relieves the pain, whether the pain is relieved by sitting, standing, lying down or by heat, rest, etc. Is the pain better when it is aggravated by coughing, sneezing or by straining? Is it better or relieved by heat? Is it better or more severe on arising in the morning, tending to subside as a result of activity and whether support relieves the pain or the patient feels just as comfortable without support.

PHYSICAL EXAMINATION

Note the patient's responses

Observe the patient carefully while the history is being taken. Note his responses whether they are quick or hesitant whether his memory is good particularly for dates and whether he is specific in respect to the nature of the accident. Note his actions when arising from the sitting position. Does he have to assist himself then? Ask him to walk about meanwhile observing his gait. Does he walk awkwardly with his body tilted forward or to one side?

The patient is then requested to undress completely. If possible watch him undress for much information can be obtained from this. How does he remove his underwear shoes and socks? I have frequently observed patients standing on one foot and balancing themselves normally while removing trousers and underwear yet when requested to bear their weight on one foot and elevate the other during the examination they will state that they are unable to balance because of pain. Frequently when a patient is requested to place one heel across the opposite knee he will state that he cannot do so yet when removing his shoes and stockings he was seen to perform this same act without apparent difficulty.

Observe body posture muscular development and muscle tone

It is natural to expect those individuals who exhibit very bad posture flabby musculature or a loss of subcutaneous tissue to have a generalized disease or metabolic process present and this will require further study.

*Ascertain height and weight**With the patient standing note the following*

1. Center of gravity position and note all defects.
2. Curves of the spine whether normal or abnormal. Is there an exaggeration of the lumbar angle or is the back flattened and the lower lumbar curve lost? Are the muscles in a state of spasm? Are there creases and gluteal folds on equal level and are the gluteal regions equally developed?
3. Motions of spine both active and passive. The curves are de-

- nined by having the patient bend forward with the knees extended. Also test for extension and side to side bending.
- 4 The presence or absence of muscle pain both local and general. Muscle spasm difficult to evaluate by the untrained examiner; a patient cannot use his muscles and exhibit apparent spasm.
 - 5 Measurements of chest expansion. This test should be performed in a supine position as it can be pathognomonic of an unsuspected Marie Strumpell disease of the spine. Practically every instance of this disease that I have seen has exhibited restriction of expansion. Expansion may be as little as 1 to 3 inches while the normal chest expansion averages from 4 to 6 inches.
 - 6 Further tests: (a) elevation of the head, (b) active flexion of the cervical spine, (c) comfortable landing on heels. These tests result in reproduction of the lesions if present or absent in all of them the patient will frequently be localized to one area.

With the patient sitting observe the manner in which he assumes this attitude and determine the following:

- 1 Motion of the spine, neck and pelvis.
- 2 Ability to place the heel of one foot across the opposite knee.
- 3 Ability to elevate the flexed thigh with and without assistance.
- 4 Ability to depress the elevated limb against resistance.

The last two tests often used in the detection of malingerers for elevation of the thigh from the chair should not result in back pain because the flexors of the thigh are the psoas and anterior hip muscles. When I warn the limb against resistance the patient with true back disturbance will evidence pain because this test requires the use of the gluteal and piriform muscles.

At this time the patient is in the prone position with the upper extremities extended forward and the head resting on the floor.

With the patient in the prone position with the upper extremities extended forward and the head resting on the floor, observe the following:

- 1 Examine at a right angle the full circumference symmetrically and record pressure. Also examine for hernia
 - 2 The examinee places himself in the all men and die gests the patient to push his hand pads back pain during this examination. He is elated in the acute case
 - 3 Observe whether the lumbar spine rests against the table or if the curve is exaggerated
 - 4 Observe the angle of motion of the joint of the lower extremities and their appearance
 - 5 Carry out the Patrick Ker or Lascoue and Gaenslen tests
 - 6 Comparative measurements: length of lower extremities from the anterior superior iliac spine to the tip of the internal malleolus the circumference of the thighs and calves
- Neurologic examination Reflexes previously tested and not elicited should be tested again Also look for muscle fibrillation lack of muscle tone and so on Sensory examination position sense of testis trophic ability peristaltic changes

With the patient in the lateral recumbency position

- 1 Test for the Ober sign
- 2 Test for direct compression through the line crests

With the patient in the ventral recumbency position that is lying prone note

- 1 Contour of the spine pelvis and hips
Points of tenderness and local muscle spasm The patient who is suspected of being a valuer should have points of tenderness marked with a skin pencil and the test repeated at various times in order to determine his accuracy of localization
- 2 The signs and symptoms elicited by hyperextension of the thighs looking for spasms referred pain
- 3 A tight and passive hyperextension of the dorsal spine This test is performed by having the patient place both hands across the back of his neck then elevate his elbows shoulders and torso from the table If the patient is lifted a lot of tension when in the erect position this same loss of tension should be manifested in this test

Rectal examination This should be carried out and the findings recorded

Roentgen ray study These should include an anteroposterior and lateral view of the lower dorsal and the lumbosacral spines and an oblique view in instances of suspected facet disturbance. It is pertinent to state here that an individual may center his complaints at the lumbosacral angle but x-ray observations in that region are negative. The pain in these cases may be referred from the lower dorsal area where an unsuspected compression may be found at either the twelfth dorsal or first lumbar level.

The patient dresses If possible he should be observed during this act.

Laboratory data sedimentation rate, spinal fluid studies by index or other injection procedures.

Psychometric evaluation of the clinician This can be a very valuable part of the routine examination.

Evil test for Dorsal Test

Some of the tests described in the following paragraphs were mentioned in essential part of the physical examination; the others will also prove useful in the evaluation of a back problem.

LASEQUE SIGN—This is known as the straight leg raising sign. It is elicited by elevating the limb with the knee extended, the examiner's hand being held beneath the patient's heel. Occasionally one notes that pain may be referred to the opposite side during this maneuver. When positive results in limitation of straight leg raising and is accompanied by hamstring spasm and localization of pain either in the lumbogluteal region or along the course of the sciatic nerve.

Brigard's Modification of the Lasque Sign—This is performed by dorsiflexing the foot at the height of the maneuver. In painful sciatica the pain is accentuated as the foot is flexed.

KERNIG SIGN—This is elicited by having the patient lie on his back with both limbs stretched. One limb is then flexed acutely on the abdomen with the knee held in attitude of flexion; the thigh is then fixed and the knee is ex-

tended. As the knee is extended pain is elicited and the localization of pain noted. Here again the pain is usually referred to the heel, calf, hamstring or hip regions.

PATRICK SIGN—In this test pain may be elicited in the lower region of the back by placing the ankle of the affected side above the patella of the opposite outstretched leg. When this is obtained the flexed knee is pressed down towards the table and one notes whether this accentuates the pain.

GAENSLER TEST—The hip and knee of the unaffected side are completely flexed on the patient's abdomen and the patient firmly encircles the knee with his arms, thus locking the pelvis. The opposite limb is then hyperextended over the edge of the examining table with the knee flexed. The mechanism thus occasioned results in a rotation of the sacro-iliac joint on the affected side and may result in a complaint of pain.

OBATA SIGN—This test is performed for purposes of obtaining information concerning a possible contracture of the fascia lata. The patient lies on one side with the limb closest to the examining table flexed and locked by means of his own hands. The examiner then grasps the opposite knee with the right hand and fixes the pelvis with the left. He then brings the limb into an abducted position. Following this procedure he slides his right hand down towards the ankle and at the same time prevents the limb from rotating internally. He then requests the patient to lower the limb towards the table. If contracture is present the limb will remain in the abducted position and if the limb is forced down towards the table pain across the lumbosacral region will result provided the area has been injured.

FREIBERG SIGN—With the patient in the prone position internal rotation of the thigh with the knee flexed results in a stretching of the piriformis muscle and in the absence of any palpable spasm or tender area situated in the gluteal deep tenderness over the piriformis raises a suspicion of disease in this muscle which may also be accentuated on rectal examination. Freiberg is of the opinion that a spasm of the piriformis muscle causes sciatic nerve irritation.

SILVERMASTER SIGN—This test is performed with the patient lying on his back and alternately raising the limbs with the

knee in complete extension. When one limb is weak the heel of the stronger side digs into the table thus indicating that an increased exertion is required of the strong limb to assist in raising the weaker one. The examiner's hands are held under the patient's heels to determine whether an increase in pressure of the heel is needed.

A variation of this test is to request the claimant to cross his arms on his chest and raise himself into the sitting position. During this test the weaker limb will swing upward with poor control.

THE JUGULAR COMPRESSION TEST—This test is performed by compression of both internal jugular veins for several seconds in order to determine whether the sign results in an exaggeration of the sciatic pain. At times even though the compression is negative a relaxation of the pressure may result in the same pain. This test has been described by Viets. It may not be positive except in those instances in which the pain is exaggerated by coughing and sneezing. Bradford and Spurling usually perform this test with the patient in the erect position and maintain compression for about 10 minutes before it is recorded as negative. They have suggested also the use of the sphygmomanometer using 40 mm. of pressure.

ANESTHESIA TEST—An excellent procedure is that of injecting a local anesthetic into the tender areas before performing these tests. The tender areas being carefully localized and marked. Following the injection if the pain is relieved and the lesions disappear it is reasonable to suppose that the traumatism is purely local and superficial and not due to a disturbance of the structural mechanism.

M m t f th Sp

As one reads the literature on this subject he is impressed with the lack of accurate knowledge concerning the movements of the various portions of the spine particularly of the dorsal and lumbar areas. It is difficult to evaluate the restriction of motion unless one is acquainted with the so called normal for the different ages period. An individual with a completely flattened lumbal may bend sufficiently forward to touch the floor with his fingers tips the moment in this case

occurring in the hips. Extension and side to side motion are readily detected while flexion is difficult of estimation.

It might well be stated that between the ages of forty and fifty years the average individual exhibits the following ranges of motion:

Flexion 60 degrees with the back well rounded

Extension 15 degrees

Side bending to right and left 15 to 20 degrees. This motion occurs mostly in the lumbar spine.

Prior to the age of forty flexion is freer and should range between 60 and 90 degrees. After the age of fifty these movements may be materially lessened depending upon the amount of degenerative arthritis that is present and depending also upon the build of the patient.

Evaluation of Physical Observations

When the physical examination has been completed and the indicated tests have been made the examiner then proceeds to summarize the positive and negative findings. In this way he arrives at his diagnosis, his conclusions as to causal relationship, and an estimate of the possible period of total and partial disability and of the loss of function.

MALINGERING

It is unfair to apply the label of malingerer until all diagnostic measures at our disposal have been resorted to. Gray in his text cites the following concerning malingerers:

The appearance of the patient is an indication of the greatest value. Remember that the malingerer is deceitful. Thus his entire aspect will be that of deceit. His eyes look shy, he has an uneasy countenance and furtive glance. Watch not the examiner under veiled droopings. If he is smart and many of them are his entire countenance may be that of the most open frankness. The cardinal point to be remembered is that the malingerer usually overplays his hand. He acts so much to tempt not to prove the truth of his assertion that suspicion appears.

Malingerers frequently ascertained that anesthetic areas are present but these are related accurately to nerve distribution. This

is equally true of the hysterical individual but in the latter one is apt to meet with a complete loss of sensation with a sharp line of demarcation, the limit of trouble is noted in glove anesthesia or stock or aesthesia.

Testing for *pnu* is outlined by Gray *et al.* of the following

In determining the pain pressure it is well to have the patient sit down. The examiner places his hand on the back of the hip and trusts that the hip be flexed against his resistance. The patient may claim pain but this should not be true since the lumbar muscles are not called into use. The examiner then instructs the patient to lower the thigh against resistance. Should there be no pain the assertion is probably false since the lumbar muscles are not brought definitely into action.

THE DISPLACED INTERVERTEBRAL DISK

In recent years it has become fully recognized that an intervertebral disk can be displaced even though the original trauma was not severe. Displacement seems to be more prevalent in those individuals who injure their backs as a result of a lifting strain particularly when the lifting strain is complicated by a torsion or twisting mechanism. In other words, a simple lifting of itself is not the true proximate cause of the trouble; it is the torsion plus the effort of lifting that is the disturbing element.

Bradford and Spurling state

The part is oft frequently complained of pain as being
 c p t at or in h r t r th p in b n l cal ed i ore patie
 ulrly in th alut l han tr n a d lo e l o m u cl es The pa n
 s f quently a s v t d r se at lly c lin eez n or
 straining th be o m gre t p r d e t de n re d i tras p nal
 press e c mpany n th ear

They state further that it is infrequent for the patient to give a history of sciatic pain at the onset. The sciatic pain is more apt to occur several days or weeks following such an injury, whereas pain in the lower back predominates immediately after the inception of injury.

It must be recognized that in disk disorders there may be lucid interval during which the symptoms subside and the

patient may resume normal activities. If recurrences are complicated by a sciatic syndrome one can then state with more assurance that the cause of the symptoms is disk protrusion and that radical therapy is indicated. Radical therapy should not be undertaken however if one is confronted with an individual who is merely suffering his first attack unless the attack lasts too long and is not relieved by the usual orthopedic measures.

It should also be noted that a disk may be displaced *without causing symptoms*. In the literature we find that approximately 15 per cent of autopsies show the presence of a displaced intervertebral disk without any clue having been recognized as to its presence prior to the patient's death.

The *pain* from a ruptured disk is usually made worse by activity for the condition naturally results in increased nerve irritation. Patients suffering from a disk protrusion often find they are more comfortable when standing than when sitting or when lying in bed.

Other manifestations of a protruded disk are (1) Obliteration of the normal lumbar curve with muscle spasm. (2) The presence of scoliosis with the convexity either toward or away from the side of pain although at times the convexity may alternate from side to side. It is more frequently noted however that the convexity is away from the side of sciatic pain. (3) Deep pressure either directly over or to the side of the injured vertebra produces pain or tingling along the distribution of the sciatic nerve. (4) There is limitation of motion of the spine during the acute phase; in the chronic phase the movements of the spine may be quite free. (5) The ankle jerk is diminished on one side and together with this there is a sensory phenomenon on the same side. In the presence of the latter findings one may be quite certain that he is dealing with intraspinal disease.

The finding of *x-ray examination* unfortunately may be absolutely negative in instances of this nature especially in those individuals between the ages of twenty and forty years; thus one should not expect to see a narrowing of the intervertebral disk space in the film. When the narrowing does occur it is usually because of antecedent degenerative disease.

and does not signify that the disk at that level is at all protruded

The use of contrast media gives us additional information. When observations are negative however one cannot conclude that the intervertebral disk has not or is not protruded. The use of air injections is popular but the results with them difficult of interpretation in the hands of the uninitiated.

TRAUMA AND DISEASE OF THE SPINE

While it is the opinion of authorities that trauma is not likely to cause disease of the spine yet it does seem to prepare the ground for localization of infectious disease processes by creating areas of lesser resistance. This fortunately occurs only in a few persons.

It is generally believed also that trauma can make manifest under certain conditions a latent infection either by producing definite signs and symptoms of inflammatory destruction or by causing inflammatory collapse of a diseased spine which heretofore had not produced any pathologic symptoms. An instance of the former is osteomyelitis of the latter tuberculosis which had been quiescent up to the time of the accident (Steindler).

Concerning the question of *osteoarthritis* and its relationship directly or indirectly to traumatism it is my opinion that *the usual case of osteoarthritis is not aggravated by traumatism as we see it in the knee unless there is also present some clinical evidence of infection*. Then the traumatism is superimposed upon the osteoarthritic symptoms or an infectious arthritis which is accompanied by blood changes and can be recognized by an increase in the sedimentation rate. I have examined in my series of x-ray plates ten of these same individuals over periods of several years and I have never been able to convince myself that there has been any appreciable amount of osteolytic fracture or dislocation by injury. It is definitely the syndrome of *traumatic arthritis* and it pertains to the joints and not to the injury or self-indisorganization of the vertebrae. I am sure of this. I do not for one believe however that this neuropathologic process takes place in the back as a result of a single act of trauma except in

where there has resulted a compression fracture which has not been corrected and where as a result of the faulty mechanism occasioned by this compression one can naturally expect mechanical irritative lesions to be set up in and about the injured area.

It is my belief that the words "aggravation of a preexisting osteoarthritis" should be eliminated from our vocabulary when they relate to back disturbances resulting from the aetiological incident. This word "aggravation" is the cause for much litigation which is frequently unfounded. Merely because the x-rays disclose osteoarthritic prolongations one cannot assume that the osteoarthritic process has been aggravated by a superimposed injury. This assumption when made known to the patient frequently leads him to believe that he will never be come well and that he will never be able to resume his former occupation. An element of fear intrudes itself and is frequently the cause of the persistence of the symptoms. Those of us who examine large numbers of patients both private and medico-legal are impressed by the fact that most individuals past the age of forty-five years whether in laborious or sedentary occupations are subject to these degenerative changes. A young person may also be susceptible to such changes in the areas of the spine that are most subject to repeated traumatism, such as the transitional levels—the fifth and sixth cervical, the twelfth dorsal, the first and fifth lumbar and first sacral regions.

It is well to pause and review the following quotations from Steindler's chapter on "Trauma and Disease of the Spine" in the book "Trauma and Disease" edited by Brinley and Kahn:

What are the conditions under which can a true relationship exist?

(1) The interval between the trauma and the occurrence of the symptom must be compatible with our clinical conception of pathological development. For instance, a shorter interval would be expected in the acute inflammatory disease which is characterized by a more intense inflammation such as tuberculous.

(2) It is frequently necessary that the injury be definitely established and that it is a legal one in the lumbar and/or of a sufficient degree of severity to produce the traumatization in the latter

respect and in the literature of trauma that the consideration of the pathologic resistance of tissues of the greater importance. Sometimes trauma produces effects in the porous and inflamed tissues that would not be produced if the spine were normal.

The literature of trauma necessary to produce a fracture in osteoporosis and in Paget's disease is naturally very much less than that which would be required to produce a fracture in normal spine.

Concerning the question of trauma and arthritis Steindler writes

A patient who had experienced a great deal of trouble with his back sustained a trauma sufficient in degree not to produce a fracture. Following this certain local symptoms appeared which were not previously and which persisted even after the immediate effects of the trauma had subsided. These symptoms which are very rarely constant and continue from the time of the accident are called by Steindler in his book "A Fracture Interval." Following the time of the accident means that the trauma has passed. If a recurrence or exacerbation occurs after the fracture interval it is likely that it is part of the normal course of the osteoarthritis.

LUMBOSACRAL ANOMALIES

There are numerous anomalies in this area and those with which we are most concerned are

Filum terminale insertion of the dural sac into the first and second sacral vertebrae

Enlarged intervertebral foraminae

Partial or complete separation of the transverse process of the first lumbar vertebra

A high lying lumbar vertebra

An increase of the vertebral body of the first lumbar vertebra which is usually associated with a high lying lumbar vertebra

High lying lumbar vertebra

A high lying lumbar vertebra is usually observed in the female whereas in the male it is usual for the last lumbar vertebra to sit well down in the pelvis so that a line drawn

across the iliac crests is midway between the intervertebral disk of the fourth and fifth lumbar segments. In the female the vertebra sits rather high so that a line drawn through the iliac crest courses through the bottom of the last lumbar vertebra. This allows of greater flexibility. Occasionally in males we observe a high lying last lumbar vertebra and this type of back is not a good one for manual labor.

Anomalies of this sort are usually painless and merely produce symptoms as a result of faulty mechanics. Such faulty mechanics cause abnormal stresses and strains which are normally compensated for by the muscular and ligamentous structures. If however these structures are injured they are then disorganized mechanically and result in a certain amount of mechanical decompensation with pain. This explains why patients suffer long continued periods of disability in the presence of congenital malformations. Yet much stress is placed upon the aggravation occasioned by the accident and the patient is treated because of this. Too much emphasis is placed upon the structural malformations and too little upon the ligamentous structures.

Lumbosacral Facet

Stability of the lumbosacral region depends in large degree upon the relationship of the facets to one another and upon their position. The most stable of these are those so placed as to be in the sagittal plane. The least stable are those that are both oblique and in the coronal plane. For these latter allow of excessive mobility at the lumbosacral angle and during the extremes of flexion and extension they are apt to be severely injured. It is in this type of back that we are confronted with protracted cases of disability resulting from injury.

Ferguson rightly states that when the facets are of the unstable variety—that is, placed in the oblique and coronal planes—they may lead to the development of a posterior displacement of the spinal column on the sacrum so that a line drawn through the posterior margin of the last lumbar vertebra courses behind the anterior border of the sacral canal. The sagittal facets allowing of the least amount of motion at the lumbosacral angle are the least likely to predispose to stresses

and strains in this vicinity. This fact is important of recognition and should aid the examiner in his evaluation.

Enlarged Transverse Processes

It is frequently noted that the transverse process of the last lumbar vertebra on one or both sides may be enlarged or



For the last lumbar vertebra, the transverse process is enlarged and bifid. This is a characteristic feature of the last lumbar vertebra. The transverse process of the last lumbar vertebra is often enlarged and bifid, which is a characteristic feature of this vertebra. The transverse process of the last lumbar vertebra is often enlarged and bifid, which is a characteristic feature of this vertebra.

may be partially or completely sacralized. Such anomalies are found in what is commonly known as transitional vertebrae which have poorly developed vertebral bodies. The transverse

tional vertebrae are almost always accompanied by a narrowing of the intervertebral disk between themselves and the adjacent vertebral segment (Fig. 18). Therefore when the examiner in reviewing the x ray observes a narrowing of the intervertebral disk between the last lumbar and the first sacral segment he should not be misled. It is quite common for this area normally to be narrowed and the posterior half is more apt to be narrower than the anterior portion.

In the presence of transitional vertebrae or congenital anomalies such disks are narrowed to a greater degree and may even be absent. This does not necessarily mean that the intervertebral disk is displaced. Displacements are least apt to occur when the transverse processes are sacralized for such vertebrae exhibit little or no movement between themselves and the sacrum.

Spondylolisth

In spondylolisthesis the articular facets of the last lumbar vertebra—that is between it and the sacral component—are noted to be quite rudimentary. In addition one may note a defect in the laminae between the inferior facet and the pedicle and such defect can also be noted before displacement takes place (Figs 19-23).

Patients suffering from this affliction may be free from pain. An abnormal stress however may result in a displacement of the last lumbar vertebra anteriorly on the sacrum because of the weakness of the posterior components of the vertebral body. This lack of stability allows of the persistence of symptoms following an injury. The injury of itself is not the cause of the displacement in most instances for comparative x rays taken before and after the accident usually fail to reveal any change in the position of the vertebra. It does however serve as an aggravating factor and results in muscle spasm and irritation.

Egg beater Lumbosacral Pain

This is a frequent cause of lumbosacral pain with or without superimposed trauma for the center of gravity of the trunk is necessarily poorly transported in these cases and as



Fig 19

f 19-A po
al m lf rm t f h l t ml
h l m d gul l pl d
f 19-B l f l
p firs d e po d l l h



Fig 130

f l f m l p l ll ra g e
c h f l f f f
p l f l d



Fig 131

F 131-A pos n
f m l l th d n d l
l ps h sa run
F 131-B La ral f l sa po
thard d e po d l l sches



F 13

f h l mb sa ral p f e
f h l sa l mb rt bra h
F 131 h

a result abnormal stresses and strains are placed upon the long spinal muscles. One can consider this angle to be within normal limits when it is less than 45 degrees from the horizontal axis. The greater the angle the greater the degree of abnormal strain taking a part in the formation of symptoms.

X RAY EXAMINATION

A A d i D t g h g b t w F t d D l f
V t b l S g m t

An interesting observation has been made concerning the relationship between the vertebral borders in fractures. In



Fg 133-L I f d d l m b p l w g d p
f mp f t f l l h d r s l g m t A l d h gh
h p r p r f h l h d r s l d h p p m f h
b f m cut gl l th t b h p m a g
d h f r t b l b d f m r gh el Th f l f ff
m k d g os f mp es fra tu

attempting to distinguish between fracture and disease of the spine one can measure the angle between the posterior verte



F 19

F 19-A pos
l m l f r m f h l s l m l
h l m d r g u l l p l d r m l f
F g 130-A l l f h
p g f r s d p d l l h e s



F 130

f l f m l p e l l l u s r a c o
g n h f l f f f
p l F g 19 d



F g 131

F g 131-A p s
f m l v a l u g b d
l p s h r u m
F g 13 -L a r a l
h d d e g r e s p o d y l h h



F 13

f h l m b l p f g
d l t l l l b r t b h
f l m p F 131 h

Physical Examination—The patient is 5 feet 4 inches in height and weighs 160 pound. He walks without a limp and without external support. His general posture is good and his musculature excellent. He stands with the left shoulder a trifle higher than the right but there is no apparent deformity of the spine. Elevation of the arms over the head and balancing weight on either foot is unaccompanied by complaints of pain. The iliac crests and gluteal folds are on equal levels and the gluteal regions are equally developed.

Movements of Torso—These movements are restricted in all directions. Flexion 10 degrees, extension 10 degrees, side bending to right and left 15 degrees, and all are accompanied by a complaint of pain across the lumbosacral region without radiation. The movements when in the sitting position are similarly restricted.

When the patient is lying in the supine position the torso is symmetrical and the abdominal examination negative. When in the prone position the torso is symmetrical, the lumbosacral angle normal and there is no evidence of muscle spasm. There is no paraspinal spasm. Deep percussion does not elicit any areas of tenderness. Although the patient complains of deep pain in the left lumbosacral angle and all about the neighborhood of the sacrum.

Movements of the Joints of the Lower Extremities—These movements are normal. Straight leg raising is possible for 80 degrees without hamstring spasm but with a complaint of pain at the lumbosacral angle. The movements of the lower extremities are equal and the neurological examination is negative.

From the clinical examination there is apparently no defect to account for the alleged complaints.

X-ray Examination—In the anterior posterior view the last lumbar vertebra exhibits many sacral characteristics. In the lateral view the lumbosacral angle is normal and there is no tendency towards instability of the last lumbar vertebra.

Impression—It is my impression that there is no evidence of an orthopedic nature to account for his complaint of pain and my report is stated. After several examinations of this patient I am of the opinion that he is well able to return to his former occupation without further treatment, in essence.

The patient was subsequently examined at different times by three surgeons, two of whom were of the opinion that the complaint did appear to be related to the sacrum. One of the surgeons reported that the patient was

bral border and the top and bottom of the involved segment. In a fracture there is most often a compression only of the upper border whereas the inferior angle is normal. In disease of the vertebrae in compression due to malnutrition there appears to be a lessening of both the superior and inferior angles (Lilis) (See Fig. 133).

We then proceed to determine whether this compression fracture is recent or remote by subjecting the patient to the jack test or forced hyperextension of the spine under anesthesia. If the compression is of recent origin one can anticipate that the deformity will be corrected if the injury is of long duration such correction will not be obtained. We cannot make a diagnosis of a recent compression fracture merely by examining the roentgenograms in every case for the compression may be within the body itself and need not result in roentgen appearances indicative of a fresh injury.

ILLUSTRATIVE CASES

Of eighty-two cases studied I have selected nine for particular consideration as illustrative of some of the many phases of the industrial back problem.

Case 1: B. K. L., 41 years, L. 5, N. 6, D. 7, P. 8, T. 9, G. 10, C. 11, H. 12, S. 13, Q. 14, E. 15, C. 16, M. 17, P. 18, B. 19, B. 20, L. 21, G. 22, G. 23.

An Italian male laborer aged thirty-three years, single, married, employed as a carpenter. On April 14, 1939, during the course of his employment, he attempted to lift a roll of paper weighing some 300 pounds with the assistance of a fellow worker. He felt a sharp pain in his lower back for which he received no treatment. Because of this disability he was totally disabled for thirty-nine days and partially disabled for sixty days. During the period of partial disability he did not return to work.

He was first examined by me on August 4, 1939, approximately four months after the accident and a similar case occurred in 1941. His chief complaints were those of a bilateral lumbago in the left lumbocrural region. He stated that he suffered pain in the middle of his back when he was doing heavy work. At the time of the examination he attempted to walk for a short distance but was unable to do so. He stated that he had not been able to walk for a long time. He had been in the hospital for a long time and was unable to walk for a long time.

exhibits a mild dorsal kyphosis with flattening of the normal lumbar curve and prominence of the long spinal muscles. When standing he exhibits a slight shift of the trunk to the right. Movements of the torso are restricted in all directions; when bending forward he has to assist himself and flexion is possible for 35 degrees. He states that he has greater difficulty in returning to the erect position.

In sitting position all movements of the spine are similarly restricted.

In the supine position the torso is symmetrical and there is no defect in movements of the joints of the lower extremities. The Lasègue, Kernig and Patrick signs are positive on both sides and there is 1 inch atrophy of the left thigh and calf. Neither ankle jerk can be elicited. There are no sensory changes. The Ober tests are negative.

Laboratory Tests—Spinal fluid studies: manometric readings normal; total protein 150 mg. per 100 cc. of fluid. X-rays of the lumbosacral spine are normal.

Diagnosis—Owing to the persistence of complaints the radiation of pain to the sciatic syndrome, the nature of the accident and the increase in the cerebrospinal protein content and in spite of the negative X-rays the diagnosis is that of disk protrusion. In my report I stated: "It is my impression that we are dealing with an intraspinal pathologic process which requires further study and perhaps laminectomy."

A neurologist who was asked to see the patient with me reported the following: "I believe that the patient has a compression of the left fourth and fifth lumbar roots. The exact nature of the lesion cannot definitely be stated without either lipiodol study or laminectomy. The patient is ill and unfortunately has no history without distortion by exaggeration. The history and physical examination enable the localization."

Unfortunately the case settled and did not come to operation. The patient received compensation for thirty-five weeks of total disability, which I believe is a high level of compensation as equivalent to \$48.00 and a lump sum settlement of \$700.00. It is not known whether he returned to his previous occupation.

C. III. V. R. B. I. Ostomy, H. F. L. W. G. L. J. R.

The patient is a white man aged thirty-seven years, a night watchman by occupation, was first seen on April 1, 1935. He stated that he had suffered pain in the midback region for three

this man and they reported. He has around a local store the greater part of the time and appears to be cheerful and does not act as if there is anything wrong with him. This report is unfair for it does not state that the patient is a man with a lumbosacral sprain or strain can be cheerful and can handle and assist but he may not be able to perform manual labor.

There is no reason to suppose that this patient suffers from a disk protrusion. Even though the disability has been prolonged it has not resulted in any of the symptoms which could be so interpreted. The fact that the last lumbar vertebra is in great part sacralized does not in any way result in a separation of a back strain nor should the spine be further stabilized for in my opinion it is sufficiently stabilized. Sacralization or partial sacralization of the last lumbar vertebra when it is symmetrical in outline and does not exhibit evidences of instability is perfectly harmless. In fact, such a vertebra appears to be much stronger and gives greater strength to the back than the lumbar vertebra with irregularly placed facets.

In view of its inability to find a pathologic condition that might account for the patient's symptoms it is my impression that the patient should be looked upon as a total geriatric.

C. H. P. babl. l. l. vert. b. l. D. k. P. t. R. H. g. f. m. l. l. ry

The patient is a white male bore aged forty-two years 5 feet 9 inches in height, weighs 160 pounds as in February 1, 1938. When in May in October 1938 he gave the following history:

As he was pushing a heavy box to full force of effort on the wheel chair in a crevice and in trying to prevent the bar from tipping he twisted his back suddenly and forcibly this was accompanied by a loud snapping sound. He suffered immediate pain but continued performing his work for another month. When he complained of numbness in the lower extremities with numbness in the left lower extremity. The pain was present in the legs at rest and was worse during the day. Coupling and squeezing aggravated the pain and he was ordered to rest the chair.

Physical Examination—The patient is a well-nourished man. He walks with a limp with the right leg supporting the weight. He is able to control the situation. The condition is not as bad as it seems. He is a good man.

in ntls but n t inc picate l Am nth l ef re e minar n
 le va tr k ac h l k l v a leav n t l l an l fr
 tlen n the pain l aue te m l ncap r t n

Physical Examination—Up v id n s n t the l p t al t l pa
 t i e n t t e m p e r a n d e a t h e l e a t e d H e e a c i t e d n l
 f f e r s a c t e p a i n H e s t a n d a n d a l k s a k w a r d l y w i t h f l a t
 l k a n d t h t h e l o n g p a n l m u s l e s i n s t a t e o f p a i n H e
 p r e s e n t s a s h a r p k y p h o s i s b e t w e e n t h e t e n t h d r s l a n d h i r t l m
 h r s e m m e n t s T h e r e i s c o m p l e t e r s t r i c t i o n o f m o t i o n o f t h e



F 134

F 135

F 136

F g 134 (Ca II) —R e g r a m f A p l 1935 h
 m f l
 f 135 (Ca II) —L r a l f h f f d p r t f t l p
 J 4 193 h l l t r e s p r o g r e s s f h l e s w h l m f
 h b r a l b d d j
 F g 136 (Ca II) —L r a l f h p m f d h l f
 v r s f s e f h l n, l l g m y t l d f h
 d l g

s p i n e i n a l l d i r e c t o s l t n d e f e c t i n t h e r a c e f m t n o f
 t h j o i n t o f t h l e r e t r e m i e A l l s p e c l t t r e n l
 n d t h e n e r l o l e x a m n t o n s n e g t i

Roentgen Examination—T h s r e c a l i e l a t y f t h e f
 e t h l r s a l e t e h a t h d n t n f t h v r t l d e t r f
 t h r h t p o t i o n o f t h e b d y T h e n t e r v r e l r a l d k l e t n
 t h e l e n t h a n d t l f t l d r l r t b r a e s a k e d l y d l d
 I n t h e l t e l e t h e e d o f t h e l e t h d r s l s o
 e t l i t n e d e o f a l s e s f o r m a t n T h e r a y a p p e

ance is suggestive either of osteomyelitis or tuberculosis (Figs 134 135 136)

Laboratory Tests—All laboratory tests were negative except the Kline diagnostic and exclusion tests which were positive

Subsequent History—After five weeks of rest in hyperextension and antiluetic treatment the patient was discharged wearing a plaster jacket Shortly thereafter he was readmitted to the hospital because of increasing weakness of the lower extremities The subsequent course of events led to a diagnosis of osteomyelitis for the patient developed a cortical abscess involving the tibia and a lesion involving one of the phalanges of his left hand Operation upon the tibia gave positive evidence of logade osteomyelitis The culture—nonhemolytic Staphylococcus aureus The patient developed a paraplegia without sensory rectal or bladder changes

The patient was discharged eight months later wearing a high spinal brace and when last seen December 1939 found a half year after the onset he had completely recovered The last x-ray examination revealed complete consolidation of the tenth eleventh and twelfth dorsal segments with loss of the intervertebral spacings At no time during the course of the disease could soft tissue infiltration suggest the existence of an abscess from which bone was detected

Inasmuch as the patient suffers local back pain for three months prior to the accident it must be inferred that the injury merely reinitiated the disease He has a adequate compensation in this respect

CASE IV K mm II Ds s of the Spine

The patient a white male laborer aged fifty years was injured December 7 1938 in the following manner With the aid of a permanent lever lifting can he moved when the anchor reached a height of 14 inches the assistant dropped the side and the lever fell on the patient He felt a dull snap in his lower back which did not fill the leg and When on November 1939 left the hospital he was found to be paraplegic and unable to walk

History of Illness—The patient exhibited a high degree of stiffness of the lower extremities and the pelvis He was unable to move the legs and the feet at all He exhibited a severe thoracic pain which was relieved by the use of morphine No local observations were negative and there is no

lapse of the fourth thoracic vertebral body and its pedicle on the left side with a soft tissue shadow on either side of this body. The skull reveals changes indicative of a metastatic lesion.

A biopsy performed on the cervical mass revealed what appeared to be an epithelial carcinoma—the origin of which was unknown. The Bence Jones test of the urine was negative.

Shortly after admission the patient developed complete loss of both sensation and motor power of the lower extremities with altered sensation to touch stimuli extending from the nipple line to the toes absent abdominal reflexes and bilateral Babinski sign. He also exhibited marked rigidity of the deep reflexes of the lower extremities particularly of the left. He was given deep x-ray therapy for relief of pain.

Discussion—The prognosis portends the likelihood is that the patient will not survive. The case brings up an interesting problem from the medical standpoint. It is the incident a competent producing unit of the metastatic carcinoma with cord involvement or was the process present prior to the time of the accident and was the process hastened by the accident?

This man had worked for the same company for several years without interruption period of illness and without accident. There are no witnesses to substantiate his statement of accident but his honest and reliable reason to suppose that he did have an accident. The weight loss of some 60 pounds following the injury with onset of cord symptoms five weeks thereafter followed by rapid progression of paraplegia.

This case still presents an opinion cannot be ventured. It is equitable to suppose here that the injury could not have preceded the malignant process but led to the formation of the metastasis which resulted in the skull and in the cervical region.

CASE VI R. L. T. 55 M. F. Th. Sp. T. L. D. et M. L. V. O.
L. C. T. Th. P. T.

The patient is a male individual, aged fifty-six years, married, born June 5, 1904, when he sustained a strain to his right lower back. He continued working and when in September, 1940, he complained of pain in his lower back that directed toward the right hip and calf which had gradually become worse and he suffered numbness of the right foot for a time.

Physical Examination—The patient height 5 feet 7 1/2 inches

atrophy. Str. i. ht. l₅ raising pos. bl. f. r. 80 d. rees and all spe. al. te. ts. are ne. g. at. e.

Roentgen Examination—X. r. y. t. ken December 14 1938 revealed l₅ht. ved. r. g. of the first lumbar vertebra. t. l. e. t. ken June 5 1939 show an incr. se. of the amou. t. of. edo.

Diagnosis—(C. m. p. r. e. s. s. i. n. f. r. c. t. u. r. of the first lumbar vertebra (Kimmell's disease) of the spine)

C. V. M. t. t. t. C. c. m. f. Sp. with C. d. l. l. m. t. C. c. d. t. l. with T. m.

On August 27 1941 the patient hit bricklaye. ved. thirty two years slipped and fell backward. injur. n. h. r. ht. hould. r. He p. t. r. ell. ht. k. for several weeks. th. ut. c. nsult. n. a. doct. r. The p. n. n. re. sed. nd. x. rays. ere. t. k. n. b. t. u. for. tunately. the. e. fil. d. did not incl. de. the. upp. r. port. n. of. the. dorsal. spine. r. the. e. cal. reg. n. Phy. i. tl. e. r. apy. d. d. n. t. rel. e. hum. S. v. eks. l. t. h. or. ced. ac. s. eakne. of. the. low. e. e. trem. t. es. ith. n. bn. an. i. he. complain. d. f. p. in. g. p. n. n. a. t. a. c. s. the. m. d. th. r. re. n.

When seen October 8 1941 the patient el. b. t. e. d. a. s. n. the. l. ft. c. r. v. al. e. l. neath. the. i. nd. l. l. a. l. est. ct. n. f. m. t. n. of. the. cerv. l. pin. M. c. f. the. d. lu. l. r. p. e. w. re. i. p. l. e. t. e. ly. re. t. ct. d. d. all. t. t. p. t. at. v. i. nt. v. e. e. ac. on. pin. d. by. vere. pan. s. th. udd. sal. H. x. i. b. i. t. e. l. t. nd. er. ne. e. h. i. s. th. p. n. p. c. s. e. f. th. v. th. to. the. t. n. th. d. l. e. tel. r. Mo. e. n. t. s. f. the. j. t. f. th. l. v. e. r. trem. t. r. n. n. l. l. l. l. j. l. t. e. t. r. n. e. at. e. T. l. e. a. n. t. r. o. p. h. y.

Neurological Examination—Upp. t. m. t. v. reflex. s. hype. t. v. e. N. l. r. l. reflex. Uppe. r. l. d. anal. fle. t. C. r. n. ter. fl. l. nt. I. o. r. t. e. m. t. v. reflex. e. n. r. k. e. d. l. s. a. s. r. tel. P. l. e. r. al. p. e. ll. r. c. l. nu. and. u. est. r. i. g. h. t. a. l. l. lon. s. R. i. g. h. t. b. b. m. k. The. e. s. n. s. r. y. ch. no. e. v. t. h. p. t. n. t. ate. i. th. t. h. h. i. f. l. n. f. m. l. e. f. n. t. l. h. t. th. r. e. n. b. th. s. d. e.

Hospitalization advised

Roentgen Examination—Upon the patient's admission to the hospital. k. afte. the. ce. d. t. th. r. v. s. re. e. l. e. d. d. t. r. u. ct. o. f. the. pin. us. p. r. e. s. and. lam. n. of. the. fifth. r. v. l. vertebra. i. d. the. l. t. r. al. marg. n. of. the. th. d. e. e. th. e. r. v. l. g. m. e. i. t. s. T. i. p. n. p. c. s. s. of. the. fifth. l. r. e. l. ab. e. n. t. nd. repla. e. d. by. d. n. s. e. s. f. t. s. c. m. s. s. Th. d. t. n. c. t.

in diameter with no local heat. The skin is freely movable over the mass and it is firmly attached to the ilium.

Movements of the joints of the lower extremities are normal and there is no atrophy. Neurological observations and all special tests are negative.

Röntgen Findings—The right ilium close to the posterior superior iliac spine exhibits an area of absorption together with a break in the bony continuity and elevation of the periosteum. This picture is one usually found in a sarcoma and not in a metastatic lesion. The pathologic area is triangular in shape and extends downward for a distance of about 3 inches with the apex pointing distally. (See Fig. 137.)

Impression—In my report I stated: "It is my impression that this is sarcomatous degeneration and is unrelated to the alleged accident as the accident was not one of direct impact. This is not a locality that would be liable to great strain when resisting a heavy object. For in this instance the long spinal muscles come into play and they are not attached to this area. The sarcoma is merely coincidental."

Subsequent History—Later the patient stated that he had struck the right side of his hip against an object. He may have struck his right hip but he was not injured in the location where the tumor originated. Subsequently it was learned that he had suffered pain in his back following urination for several years.

Following my examination he was referred for an aspiration biopsy; this revealed a spindle cell sarcoma. The pathologist's report dated September 9, 1940, states: "The tumor had nothing to do with injury. The injury was light and the symptoms developed gradually. The time intervals are inconsistent with a traumatic lesion."

The patient died March 6, 1941, and in a report dated November 8, 1941, the pathologist stated: "The injury of June, 1940, did not cause or aggravate the malignant tumor. The cause of the history of back pains in 1938 and difficulty with urination of long standing. The patient's death was not caused or hastened by the injury."

The case is difficult of evaluation. It must be admitted that the patient and his physicians were not aware of the fact that he suffered an illness when they reported the condition as being due to a local trauma. If the accident had been competent producing cause of the disease since he was over the chance of events would have been a local trauma. The case is not a simple one.

Weight 137 pound. He exhibits in extreme lateral kyphosis with secondary lordosis and lateral waddling gait.

Movements of Spine—Flexion of the lumbar vertebrae only about 10 degrees of the normal curvature. The thoracic spine of 10 degrees but none of this occurs in the spine.



F 137 (Case VI)—The following photograph shows the lateral curvature of the spine.

bending to right and left 10 degrees. These movements are accompanied by spasm of the longitudinal muscles. In the sitting position the movements are similarly restricted.

With the patient lying on the posterior table the trunk is held rigid. The only point of tenderness is the right iliac saddle and midline adjacent to the lumbar rest. In this case the habit is a soft tissue as well as the

July 1938 he complained of pain in the lower back and stated that his lower extremities felt heavy.

Examination—The patient's height is 5 feet 6 inches and his weight 140 pounds. There is complete restriction of motion of the spine, his back is flat and there is loss of the normal lumbar curve but no muscle spasm. Straight leg raising is normal and the neurological observations negative. His chest expansion is limited for a patient of his age.

Roentgen Findings—Failure of fusion of the laminae of the first sacral segment. Both sacroiliac joints are moth eaten. In the lateral view the crumpled place is posteriorly approximately 1 1/2 inch. (See Fig. 138.)

Diagnosis—Early Marie Strupp disease of the spine unstable lumbosacral spine.

My report stated: *The accident did not create the pathologic process but the injury could very well have accentuated the pain.* Because of the disease of the spine it is expected that his return to the pre accident status will be delayed if the patient were older the period of disability would naturally be greater.

The subsequent course unknown. He is a settled and the patient is allowed to remain at a net sixteen weeks of temporary disability amounting to \$400.00 and lump sum award of \$500.00.

Case VIII. F. J. S. of Spine

A white male, 1 do, clean, aged forty three years, as injured February 1939 when he fell 14 feet and landed on the pavement on his left heel. He sustained a fracture of the first lumbar vertebra with a comminuted fracture of the left os calcis. When seen September 8, 1939, seven months after the accident he was paraplegic.

Examination—He is flexed spine 40 degrees with the back well rounded. He is able to perform extension 5 degrees and side bending to right and left 10 degrees. The routine examination is essentially negative except for the fracture of the spine.

No treatment as directed. He died shortly thereafter. He recorded the following final no further spinal complaints.

Reign of Fear—He ate a cup of the first limb fracture of the spine with the back piece between the tenth and the first lumbar vertebrae.

When last seen, fifteen months after the injury, the range of

th injury wa a d r e t o n e n d n o h i s t o r y o f a n y l e a l c o n t i n u o u s
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TABLE 1

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T t g		6
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Cr u h g u n j es		3
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A t m l l	d t	3

TABLE 2

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t ro	30 0	65 0	716 00	1487 00	582 00
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M S mpell p	16 0		400 00	200 00	14 00

in tension of his spine had increased and no venient were put upon him. He stated that if his condition remained the same his form of occupation

CASE IX. Spinal Osteoporosis and Arthritis

A white male hospital orderly aged sixty-seven years was injured May 5 1936 he picked up a patient and fell on the spine in his back. After five weeks of bed rest he returned to work and performed part time work until February 1938. When seen April 18 1939 he complained of pain across the lower back with difficulty in walking down steps.

Examination—He is in poor general condition 5 feet 9 inches in height and weighs 151 pounds. He exhibits slight muscle spasms marked muscle tremor and tenderness of the lower back. All movements of the spine are restricted and accompanied by pain and muscle pain. When lying on the supine and prone position there is complete loss of the normal lumbar curve. He exhibits bilateral postspinal tenderness of the lower vertebral column as does the anterior. There is no atrophy and the neural elements are not enlarged.

Roentgen Findings—Marked osteoporosis of the entire spine. The lumbar section shows the anterior vertebral bodies complete fusion of the right sacro-lumbar articulation and irregularity of the left. In the lumbosacral region there is total osteoporosis of the vertebrae from the anterior margin of the lumbar spine.

Impression—General osteoarthritis—not associated by accident.

It is not rest to him to be able to perform his usual work for ten years following his accident that is to say he is present with only five weeks of bed rest and is still disabled because of the accident.

The accident occurred December 30 1939 he has awarded compensation for forty-nine weeks of partial disability and a lump sum of \$1200.00. It is not known whether he turned to his business.

REVIEW OF CASES

As stated previously the series under review included eighty-two cases. These were thoroughly studied by me many of the patients being hospitalized for such study but none was personally treated. An historical data concerning the his-

was fused. This operation was performed prior to the traumatism for which I examined her. When seen by me two years after the operation she insisted that the pain had been more severe following the operation than before it.

One patient was subjected to a coccygectomy without any relief whatsoever. In fact the three patients with *coccygodynia* developed an anxiety neurosis which was quite persistent in character.

Four patients had *Oler operations*. Of these three were operated upon following compensable injuries and all three stated that their conditions had not improved as a result of the operation. The other patient for whom the operation was performed because of a sciatic syndrome two years prior to the accident stated that the operation had relieved him of all his discomfort. *It is therefore difficult to measure the amount of relief obtained from such operations in the compensable case.*

Two patients had the *gluteus maximus muscle stripping operation*. One of these had had the Ober operation performed prior to the accident and he insisted that the combined operations had relieved him of his sciatic syndrome. The other patient stated that he was not benefited by the operation.

Two patients were subjected to *laminectomy for disk protrusion* with negative findings at the time of operation. In both of these cases the pain persisted after the operative intervention.

In this series there were three cases of *Marie Strumpell disease of the spine* complicated by injury. In none of them was the injury of itself a competent producing cause of the disease as we recognize this affliction and the injuries were not sufficient to cause more than the usual sprain. In spite of this the patients received compensation for a period of time on the grounds that the accident aggravated the pain.

Of the cases of *unstable fifth lumbar vertebra* four exhibited definite degrees of spondylolisthesis and in all X rays taken over a period of years were studied and compared. There is no change to be noted in the late X rays as compared with the earlier ones. The accident in these cases was

story of the injury are given in Table I. Table presents data showing the duration of the disability and the compensation and medical costs. A review of the latter compilation seems to indicate that the cost of compensation in the average case of back injury in New York State far exceeds that of the general average throughout the country.

ANXIETY NEUROSIS

Of the eighty-two cases examined for this study, the number diagnosed as anxiety neurosis was twenty-five. The time elapsing from the date of accident until the time of my examination varied from less than six months in one instance to forty-eight months and upward in eight instances. It is my feeling that the longer the symptoms persist and the longer the case drags out, the greater the chance for the development of a traumatic neurosis.

My records show that anxiety neurosis is more frequently observed between the ages of forty and fifty years in males and between twenty and thirty years in the comparatively small number of females I have had occasion to examine. The only reason I can ascribe for the occurrence of anxiety neurosis in men in their forties is that at this age they feel that they have reached their maximum of efficiency and an accident at this time instill in them the fear that they will be unable to resume their former occupation. Prior to the age of forty it is comparatively easy to elucidate the problem of back injury by means of a monetary arrangement which in a short time enables the patient to resume his former occupation or some new occupation for which he is physically suited. After the age of fifty it is to be expected that the individual will be less fearful by this time he knows he has reached his maximum of efficiency and is almost ready for a change of occupation or retirement. For he may depend upon his children for support. In that decade between the ages of forty and fifty we have the most trying financial problem to cope with.

Operative Results

In one young patient relief was obtained of spinal irritation was made and became further moistened and cleared up.

Early hospitalization followed by a definite system of therapy would save the insurance carriers enormous sums and would return the worker to gainful pursuits sooner than is often the case without such planned therapy. It is my opinion that patients with back injuries are usually overimmobilized and too little attention is paid to exercise and psychotherapy. The propensity to operate or manipulate under anesthesia and to follow this by long periods of immobilization is to be seriously condemned.

CONCLUSIONS

As the result of my observations in the eighty-two cases which I have reviewed as a preparation for this paper I have come to the following conclusions regarding the industrial back problem:

1 The mechanism of a back injury is the direct clue to the underlying disease process. A twisting strain during a lifting injury should be suspected as a cause of disk protrusion. A lifting effort in an elderly patient may be productive of a compression of one or more vertebrae, this being more particularly noted in the mid and lower dorsal regions.

2 The x-ray may be negative in the presence of a true disability of organic origin and highly positive in patients in whom pathologic change is minimal and even in those who can be classified as malingerers by a competent physical examination and investigation.

3 Intervertebral disk disturbances are frequently unaccountable for negative roentgen ray findings.

4 Congenital malformations of the spine are not the cause of disability; they may, however, be contributory factors when an unstable fifth lumbar vertebra is noted.

Injury does not accelerate osteoarthritis unless it can be proved that there is a definite progression of the change (x-ray).

5 A fracture of the twelfth dorsal or first lumbar vertebra may result in pain referred to the lumbosacral mole; this indicates that when the mechanism is such as to suggest this possibility, the injury should be x-rayed.

7 Cases of back injury should be referred to the physician who has had a large experience with them so that they

stated to be a competent producing cause of aggravation of the condition

All the patients after the age of forty disclosed evidences of moderate *osteophytic prolongations* at the transitional levels and the degree of these prolongations depended upon their occupations. Only in the older patients was the osteoarthritis generalized. It is my impression from the data obtained that the *osteophytic prolongations* studied roentgenologically over a period of years failed to reveal any progression. In other words these were mechanical prolongations that antedated the accident; they were not due to traumatism and therefore were not progressive in character. The accident merely created a sprained back superimposed upon the pre-existing mechanical arthrosis. Yet such patients can claim disability for varying periods of time. Again as mentioned previously the element of fear is a large one particularly between the ages of forty and fifty years.

There was one case of *Paget's disease* complicated by an accident in which it was alleged that the accident aggravated the pain.

COMMENTS ON TREATMENT

Cases of back injury should be referred to those physicians who have had a large experience with them so that they may be properly evaluated and treated. They should be seen by the specialist within three months after the accident and sooner if possible and not one or more years later for then the symptoms are thoroughly masked by extraneous factors and their evaluation is most difficult and even impossible. This course is wise both economically and socially.

The element of fear must be combated from the first. Rehabilitation of the patient by means of occupational therapy must be instituted early so that he will not be left to sit about from day to day continually becoming more and more self-centered. It is because of having nothing useful to do that the average individual develops dissatisfaction with his lot, with his physician, with the insurance companies and with the State.

CONGENITAL DISLOCATION OF THE HIP

G al C d t ns a d System f C r t e Treatme t

ARTHUR KRIDA M D F A C S

CONGENITAL dislocation of the hip is a defect in the prenatal development of the hip joint which exhibits familial racial and sex linked characteristics

Females predominate in the ratio of six to one Northern Mediterranean races are prone to it In New York City Italians Central Europeans and Jews constitute the vast majority of patients with this condition as seen in orthopedic clinics

The affection is bilateral in about one half of the cases when unilateral the left hip predominates in the ratio of about ten to one

Congenital dislocation of the hip is a defect which in infancy and early childhood is manifest by comparatively minor disturbances of form and function but which with increasing age becomes associated with progressively increasing physical incapacity From a therapeutic standpoint the condition is curable only in the phase in which it is accompanied by a minimal functional disturbance and becomes progressively less amenable to treatment the greater the associated disability which is another way of saying that the only period during which congenital dislocation can be cured is in infancy and very early childhood and that therapeutic efforts after this time can result at best only in amelioration

While it is possible to make a diagnosis of the condition prior to the time the infant begins to walk in a practical sense the obvious symptoms manifest themselves from the time that ambulation is undertaken

may be properly evaluated and treated. They should be seen as soon as possible after the accident and not several years later when their evaluation is most difficult.

8 Early hospitalization followed by a definite system of therapy is desirable. It is my impression that many injured backs have been overimmobilized and too little attention has been paid to exercise and psychotherapy. Lagerness to operate or manipulate under anesthesia and to follow this by long periods of immobilization is seriously condemned.

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monest being the general muscular hypotonia incident to severe rickets. In any event the x ray clarifies the diagnosis and demonstrates that the femoral heads are not in the acetabula.



l g 140-P g d f n y Th v h l l
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m d

In this phase there is no complaint of pain and secondary structural changes are at a minimum.

Symptoms Lat Childhood Adult

As time goes on the disturbances of form and function increase progressively. There is as yet no pain but there is complaint of *weakness* and *fatigue*.

The dislocation may vary from a subluxation to a complete dorsal iliac displacement. The femoral head may have found a resting place beneath the anterior superior spine or may have progressed backward and may have developed a secondary acetabulum somewhere on the side of the ilium or the head may be completely free in the muscular tissues posteriorly, thus constituting the complete dorsal iliac dislocation.

The x ray will show that the original acetabulum is very shallow or nearly obliterated, that the head of the femur has lost its rotundity to a variable degree and that the neck of the femur appears still further shortened.

SYMPTOMS

Symptoms of Early Childhood

UNILATERAL DISLOCATION—In most cases the mother brings the young patient in seeking an explanation for a slight *asymmetry* of the limbs which she has noted and for the *limp*. On examination the affected extremity is seen to be a little short. There may be some slight atrophy of the thigh the trochanter is felt to be a little high and there usually is a slight degree of restriction of motion in the abduction range. Other me-



Fig. 139—X-ray of the hip joint showing the femoral head and acetabulum. The femoral head is displaced from its normal position, indicating a dislocation. The acetabulum is also visible, and the femoral neck is shown. The image is labeled 'Fig. 139' and 'X-ray'.

ments are usually quite free although hyperextension sometimes is also limited. The *Trendelenburg sign* is present.

The *x-ray* will show that the femoral head is not in the acetabulum and that the epiphysis of the dislocated hip has ossified to a lesser extent than that of the normal hip. The *x-ray* will also show frequently an apparent shortening of the femoral neck which will be discussed later.

BILATERAL DISLOCATION—In bilateral cases the abnormality of gait which is noted is a variety of *addle* which has frequently been referred to as the *duck addle*. It is true that other conditions may imitate this duck addle the con-

monest being the general muscular hypotonia incident to severe rickets. In any event the x ray clarifies the diagnosis and demonstrates that the femoral heads are not in the acetabula.



Fig. 140—Pelvis of a child, showing the femoral heads in the acetabula. The femoral heads are not in the acetabula, but are displaced laterally and posteriorly.

In this phase there is no complaint of pain and secondary structural changes are at a minimum.

Symptoms in Late Childhood and Adulthood

As time goes on the disturbances of form and function increase progressively. There is as yet no pain but there is complaint of weakness and fatigue.

The dislocation may vary from a subluxation to a complete dorsal iliac dislocation. The femoral head may have found a resting place beneath the anterior superior spine or may have progressed backward and may have developed a secondary acetabulum somewhere on the side of the ilium or the head may be completely free in the muscular tissues posteriorly, thus constituting the complete dorsal iliac dislocation.

The x ray will show that the original acetabulum is very shallow or nearly obliterated; that the head of the femur has lost its roundness to a variable degree and that the neck of the femur appears still further shortened.

Symptoms Adult Life

The symptoms and signs described in the preceding section become more pronounced in adult life but there is one symptom which has not been present before and that is *pain*. If there has been formed a secondary acetabulum osteoarthritic changes will develop within it and produce pain and limitation of motion in the hip. If the head is found to be lodged antero-



Fig. 141—Posterior view of hip joint showing dislocation of femoral head. (Krider, 1914)

laterally in the soft tissues beneath the anterior superior spine there may be little or no pain. If the dislocation has become a complete dorsal iliac one there will be no development of arthritis in the hip joint but there will be symptoms of pain and weakness in the lumbar spine due to the secondary increased lumbar lordosis.

THERAPEUTICS

A substantial cure of congenital dislocation of the hip is possible in a large majority of cases if treatment is undertaken in infancy or very early childhood—the earlier the better. Only occasionally is it possible to achieve a substantial cure after three years of age. All treatment after this age is to be looked upon as being *palliative in nature and capable of result*

ing only in a variable degree in approximation to a normal hip joint. This discussion is concerned only with cases in the age group in which a substantial cure of the condition is possible.

Historically it may be mentioned that prior to fifteen or twenty years ago the results of treatment of congenital dislocation of the hip by manipulative means were conceded to be very poor; consequently many surgeons turned to the open operation as the only means of bettering the results of treatment. This is still the practice in some clinics for the age group under consideration. Since 1935 I have felt that the results of treatment by measures other than open operation could be materially improved first by recognizing that an age group exists which is favorable to treatment and secondly by earlier diagnosis and the elaboration of a more careful technic of management. I have resorted to open operation only when lesser measures have failed, which has been rarely.

The Aetiology and System of Treatment

Two sets of factors are recognized: (1) the dislocation itself and (2) the secondary changes in the soft tissues and in the bones. The changes in the *soft tissues* which constitute a bar to successful reduction and maintenance of the reduction consist of abnormalities and contractures of the ligaments and soft structures about the hip joint. These are developed to only a mild degree in the early phases of the dislocation and rarely constitute an obstruction to reduction by a simple manipulative procedure.

The secondary *bony change* that is frequently present at this time is a structural change in the upper portion of the femur consisting of an anterior distortion or so called an "reversion" of the femoral neck (Figs 14-143). This does not constitute an obstruction to reduction but it does constitute a hazard to the security and permanency of the reduction. This distortion in my experience has been found to be present in about two thirds of the cases. The present system of treatment contemplates the reduction of the dislocation by manipulative means together with the correction of the secondary structural bony defect when found in the course of the treatment of the dislocation and not at a subsequent time.

TECHNIC OF REDUCTION AFTER CARE—The patient in the supine position is anesthetized by the open drop ether method. The adductor contracture is overcome by digital pressure in abduction and during this maneuver the hip is frequently replaced. If the hip has not become replaced the thumb of one hand is placed behind the trochanter and with the other hand the limb is abducted the trochanter thumb acting as a lever. No undue force is used. If the hip does not become



FIG. 144—X-ray method of hip plaster fixation in abduction.

replaced relatively easily, further attempt at manipulative reduction is given up and the patient is submitted to open operation.

When the hip has been reduced a plaster fixation splint is applied in the 90-90 degree position (Fig. 144). This position is maintained for two weeks when at a second sitting the position is changed to one of lessened abduction and more or less internal rotation (Fig. 145). The degree of internal rotation that is now required in order to place the head deeply in the neck of the acetabulum is an expression of the amount of anterior dislocation which is present in the femur. If the amount of internal rotation that is required to accomplish the best apposition

tion of the head to the acetabulum is slight then this maneuver constitutes the final maneuver in the treatment of the reduction and the plaster of paris spica is allowed to remain in position for five months.

TREATMENT OF ANTERIOR DISTORTION OR SO CALLED ANTEVERSION—If it has been found necessary to impose a considerable degree of internal rotation upon the extremity in order to secure the best relationship of the head to the acetabulum I correct the anterior distortion in the course of the treatment at a third sitting at the end of three months. At this time the structural defect of the femur is corrected by *manual supra*



Fig. 14—Anterior view of hip fracture in plaster.

condylar osteoclasis. The bone which has been seen to atrophy during the fixation in plaster of paris fractures early and internally at a point but little inches above the epiphyseal line. One has to grasp the trichter in the head of the femur and maintain its mobility until it is in the center rotates the lower femoral fragment until the again placing the knee joint in the normal anteroposterior plane without having to take any artificial relationship of the head to the acetabulum which latter requires the inwardly rotated position (Fig. 146).

A plaster-of-paris spica is applied with the limb in a

abduction and slight flexion at the hip and knee (Fig 147). The fixation is maintained for another three months thus constituting a total period of fixation of six months.

I would like to emphasize if I have not already made it clear that the structural distortion of the femur should be corrected in the course of treatment rather than after a redislocation has occurred on this account. This will bear em-



Fig 146—X-ray of femur showing lateral bowing.

phasis since I have had occasion not infrequently to observe cases treated elsewhere in which this question arose and which were allowed to proceed to redislocation before the correction of the anterior distortion was undertaken.

I am of the opinion that correction of the anterior distortion is necessary since there has been advanced no evidence at any time that this distortion is subject to spontaneous cor-

location took place. The hip then was again placed in internal rotation and at the end of the usual time a manual osteoclasis was done and the distortion corrected. As a result the hip has remained in place for the last two years.



Fig. 149-A. f f f g l d l t f t l f l p m d
f h t f h l d l d t m

RESULTS—I am repeating here the statistical material published by Colonna Carr and myself in 1936. Subsequent observations have served to confirm that at least as good results as those outlined may be attained by the meticulous use of this technique.

RESULTS	NON-ANESTHETIC	STRETCH		
		C	F	P
Unilateral		75%	19%	6%
Bilateral		65%	1%	18%

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THE PRESENT STATUS OF THE SURGICAL TREATMENT OF BONE AND JOINT TUBERCULOSIS

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IN ATTEMPTING to evaluate surgical therapy in bone and joint tuberculosis one must be cognizant of the fact that the literature prior to 1920 with few exceptions is of little value. The reason is that errors in diagnosis prevailed. The end results reported in that era appear fantastic in the light of our recent operative results. This is all the more true when one realizes that a positive diagnosis is most difficult even with our more scientific tests.

PRELIMINARY CONSIDERATIONS

I will attempt an evaluation of surgical therapy in bone and joint tuberculosis in the light of recent statistics and with respect to the following factors: (1) diagnosis, (2) age of the patient, (3) location of the disease.

Diagnosis

Joint involvements were often erroneously diagnosed as tuberculosis in the past and patients were treated for tuberculosis though the diagnosis was not subsequently proved. This is particularly amplified by earlier statistical studies. Rollier reported 85 per cent excellent results in a long series of conservatively treated cases, claiming an end result of normal motion in 40.6 per cent of his cases of tuberculosis of the hip, in 58.4 per cent of tuberculosis of the knee and 66.6 per cent of tuberculosis of the ankle, whereas from the New York Orthopedic Hospital where the cases were more scientifically studied the percentage of cures with normal

Ass	Cl	cal	P	fec	f	Orth	p	d	S	g	ry	Co	ll	U
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

range of motion was reported as almost infinitesimal. At that institution in 1944 Allen Smith reported a diagnostic error of some 38 per cent. At Steindler's clinic in 14 cases diagnosed clinically as tuberculosis there was an average error of 36.1 per cent. Isn't it likely, therefore, that those cases wrongly diagnosed as tuberculous resulted favorably, rather than those that actually were tuberculous in nature?

It should also be stated that in fourteen cases (if proved) of intratuberculosis Allen Smith reported that the guinea pig test was positive in ten and negative in four. This test is generally supposed to reflect accurately the presence of tuberculosis but it is evident that it does not do so. *Tuberculin* tests alone are not reliable and often leave the physician in a quandary. Patients are led to believe that tuberculin, guinea pig and other such tests are invariably positive in the presence of tuberculosis and that if they are negative they don't have tuberculosis.

Of all diagnostic measures biopsy gives us the greatest amount of information but Ghormley and Allison report that even this test is not always of real value. When performing a biopsy one should take several sections of synovial tissue and subject them to slide study and guinea pig inoculation. Ghormley suggested that it is easier to inject two guinea pigs at the same time for one may die early without giving us any useful information.

A long period of time is required for establishing the diagnosis in some cases of suspected tuberculosis—in many instances two or more years. During that period the diagnosis may be merely suspected. In view of these facts it is difficult to evaluate the older studies of end results.

Agitation Patient

In the past it was felt that the convalescent status of the patient was not to be considered in the treatment of tuberculosis of bones and joints; therefore orthopedic surgeons were prone to rely solely on the more costly conservative therapy. Furthermore, it was believed that children respond more favorably to conservative care. It was not deemed advisable to operate upon children because of the frequent failure to obtain

solid bony fusion in the larger joints and in the spine. Sufficient time had not elapsed for consolidation of the disease to allow of an early spinal fusion.

Most orthopedists today are in agreement that conservative management is best before the age of fifteen years, but that after this age operation is indicated. During the latter age period the patient treated by conservative means develops a poor psychological outlook. His education frequently is neglected, as is his vocational adaptability. He becomes tuberculosis conscious and lives a more or less secluded life, always fearful lest he have a recurrence. I have seen many of these fearful patients outlive their parents, brothers and sisters, and throughout their lives they have been an economic drain upon their families and upon the community in which they live. It is because of these facts that it is far better to operate in this age group even though conservative therapy may be equal or superior to radical cure, for operation lessens the chances of creating a permanent physical and mental invalid.

Unfortunately, in most instances surgery does not eradicate the disease and consequently is not a curative procedure. In orthopedic surgery of tuberculous joints one merely attempts to arrest the disease by eradicating motion. The aged do not respond well to surgery of a constructive nature and ablation of the affected limb is often necessary to save their lives or to lessen the period of disability and toxemia.

Length of Disease

Tuberculosis affects weight bearing structures in the following order of frequency: spine, hip, knee, ankle, long bones. Surgery plays a large role in the treatment of weight bearing areas for it tends to lessen the economic burden and the chances of recurrence. Recurrence in tuberculosis may follow surgery; it is however more apt to follow conservative therapy. For long ankylosis rarely ensues. The conservatively treated patient is left with a joint that exhibits fibrous fixation with perhaps a minimum amount of motion. This range of motion may extend from 10 to 40 degrees, not sufficient to be useful yet sufficient to allow of repeated spraining and straining of the affected area with danger of recurrence.

Phases of the Disease

The following grouping is taken from Cleveland's writing, and has been found to be most useful in the evaluation of therapy.

Group 1 The patient with tubercle of the pleura here is

Group 2 The one with pulmonary tubercle and a local negative sputum and without metastatic spread to other organs

Group 3 The patient with not only a disease of the lung but also is afflicted with pulmonary tubercle and infection of the pleura

Group 4 Those with pulmonary tubercle and not a spread to the other organs

These are called the following

Group 5 Rheumatoid pleuritis tubercle of the costal and velvety areas of the very high incidence and in reality the disease invariably they are afflicted by both pulmonary and tubercle

Group 6 Bone and joint tubercle with the disease of pulmonary tubercle but completely the presence of a case of infection with or without a case of infection of the

A study of the mortality statistics relative to both conservative and radical therapy in the light of the assembled facts has shown itself to be far less in those cases classified groups 1 and 2 and the greatest in group 3 + 4 and 5 irrespective of the type of therapy resorted to. It is almost foolhardy to attempt surgery in group 4 whereas in group 3 the attention should first be directed to pulmonary fields for here is the primary focus. If the patient responds well to pulmonary care he then will definitely respond well to surgery of the involved joint.

Ample Time

The aim of the local treatment of the tubercle in the case are as follows

- 1 To prevent deformity and to favor local healing by rest in a carefully chosen posture For example should the disease involve the *spine* the patient is placed in moderate extension When the *hip* is involved the limb is placed in an attitude of abduction extension and neutral rotation
- 2 To restore free movement whenever possible If this is found to be impossible then sound ankylosis should be sought through the use of surgery
- 3 The removal of the diseased area of bone here there is involvement of a shaft or small focus close to a joint by excochleation along the line of treatment for osteomyelitis
- 4 To prevent sinus formation and secondary infection
- 5 To prevent loss of life by ablation of a limb when necessary

TUBERCULOSIS OF THE SPINE

Operative fusion is an incident in general treatment of this disease but it should be realized that the timing of the operation is of considerable importance It has been observed by Swett Bennett and Street that healing rarely occurs in the presence of a local tuberculous spinal abscess and that this lack of healing is more marked after the abscess is calcified or if calcific debris remains in the vicinity of the lesion (Figs 149-150) They have also observed that healing usually follows the disappearance of the abscess It has been concluded by many authorities in recent years that there is no advantage in the operative treatment over the conservative treatment with exceptions These exceptions will be considered shortly It is also the opinion of authorities that there is no essential difference between the merits of the various forms of spinal fusion Observations have led to the following conclusions That healing is proportionately more frequent as one descends the spinal column that is healing is far less frequent in the dorsal area than it is in the dorsolumbar region and far less frequent in the latter than in the lower lumbar area Lumbar tuberculosis heals unusually well within a period of from two to three years irrespective of the method of treatment The dominant feature in the healing of Pott's disease lies in the

occurrence the behavior and the disposal of the abscess. This is a most important observation.

It has been shown by Sweet, Bennett and Street that while healing occurred in 35 per cent of total cases it took place in only 19 per cent of those in which a persistent abscess was reported. The percentage of healing increased to 59 per cent following disposal of the abscess. On the other hand other



Fig. 149—Lateral view of female patient, aged thirty-three, with fibrous tubercular abscess of the right mandible. The abscess is located in the lower jaw, extending from the chin area towards the ear. The patient's hand is visible near the abscess.

observers have been of the opinion that the presence of an abscess does not materially influence the disease and that as the abscess calcifies the prognosis improves. An increase in abscess formation is a poor prognostic sign. Furthermore, it has been believed in the past that the abscess disappears as a result of immobility. This is not altogether true for it has also been noted that an abscess may recur even after spontaneous

An abscess may occur any time during the life of the individual even though the patient has been previously pronounced as clinically cured.

TREATMENT OF THE TUBERCULOUS SPINE AT DIFFERENT AGE PERIODS—In *childhood* conservatism should be practiced unless the patient and the family are uncooperative or the disease progresses in spite of treatment. In these instances



Fig. 150.—Tl d p l p rs f b f rm h
 l fi rs f g h h ff d t l f h l mb
 l p h g f gh H h b bl b g f llv
 pl v d Th l l h lf h b t f ry tum
 A l m f m m l l b d f d h g g
 l l h l p rs d f

operative intervention may be undertaken with the hope that it will result favorably. It should be noted that deformity will progress irrespective of the treatment and it has been my belief that the disease will remain active for longer periods of time if too strenuous attempts are made to prevent deformity. Hyperextension or early spinal fusion is not indicated since it serves to keep the diseased area apart and does not allow

of consolidation. Chest surgeons resort to collapse therapy whereas orthopedic surgeon reverse the procedure preventing healing by hyperextension. It would be better to allow consolidation of the process by lessening the extension and even going so far as to allow the formation of a slight deformity.

After the age of fifteen years it is better to treat patients conservatively until the reparative stage sets in and then to fuse the spine so as to lessen the economic drain and prevent psychotic factors from playing a part in the future welfare of the patient. In the presence of abscess formation wherever possible drainage should be effected. This is particularly true of the large mediastinal abscesses for they militate against healing.

TUBERCULOSIS OF THE HIP

In comparing the therapeutic results in tuberculosis of the hip treated by operation and without operation as published by Girdlestone of England we note the following:

	Non-operative	Operative
Total treated	130 patients	133 patients
Still disabled	7 (5%)	87 (66%)
Useful	18 (14%)	1 (1%)
Complete	14 (11%)	13 (10%)
Satisfactory	6 (4%)	5 (4%)
Dead	17 (13%)	11 (8%)

From the tabulation it is apparent that the end results are practically the same irrespective of the method used.

In this country Smith and Watters in 1938 reported a series of cases of tuberculosis of the hip treated conservatively. This disclosed a mortality rate of 74 per cent with activity of the disease still present in 40 per cent, only 27 per cent were in the quiescent stage and in these but little motion was present in the hip joints. This series was taken from the New York Orthopedic Hospital and Clinic.

In 163 cases in which fusion was done at that same institution as reported by Hall and Gormley only 18 per cent were failures, the causes for failure being faulty technique and

improper immobilization. Similarly favorable statistics are available from other clinics.

The treatment of choice in tuberculosis of the hip irrespective of the age of the patient is conservative until nature has begun consolidation of the disease at which time *operative fusion* is indicated. This operation can be performed routinely unless there is a contraindication such as dissemination of the disease or debilitation. It is to be noted that operative fusion can safely be performed in the presence of active tuberculosis even in the presence of abscess formation. Sufficient statistics are now available to show that operation in no way interferes with the growth of the affected part. *Resection* is rarely employed; it is performed only for drainage purposes where there is extensive destruction and persistent sinus formation to the extent that the patient's resistance is very much lowered. *Disarticulation* is recommended for extreme cases in order to save life.

TUBERCULOSIS OF THE KNEE JOINT

In dealing with tuberculosis of the knee joint one must take into consideration several factors. A purely *synovial* variety metastatic from some other focus may be present and may never involve either cartilage or the bone. I am in agreement with Girdlestone that such a lesion does exist and in fact have seen several of them. The outlook in such cases is favorable in children following conservative care. This disease may persist for many years without spreading either to other joints or by continuity to the neighboring cartilage or bone. I have personally followed one such case for some twelve years and have seen several others whose history dated back twenty-eight years. In adults neither conservative therapy nor synovectomy is of any value.

Girdlestone reports fifteen instances in children who were treated for over a year or more after treatment had failed. Of these nine exhibited full movement, two abutted joint, and four had limited movement. Two were still under treatment and the new subjects to operation with resultant union in the average period required for obtaining full movement in the nine who were treated conservatively was

formation. On pathologic study of both the fused knee and surrounding tissue no evidence of tuberculosis could be detected. Instead trichinae of the encysted variety were found. Since the amputation of the limb the patient's recovery has been entirely satisfactory.

TUBERCULOSIS OF THE FOOT AND ANKLE

In *children* the outlook for conservative therapy is good provided this treatment is consistently carried out under proper supervision. Humphrey and Durham reported a series of twenty-nine children suffering from affliction of the ankle; of these fifteen obtained full function. Rollier and LaGrosso reported 90 per cent cures in both adults and children as the result of conservative therapy. According to Steindler the indications for conservative therapy are young children and adults excepting those with isolated intra-osseous lesions, adults with mild synovial infection and isolated osseous formations and also those who are not amenable to operative treatment.

Miltner and Fang, in a paper dealing with tuberculosis of the bones of the foot, divided the disease into two main groups. The first of these is that in which the lesion starts in the central portion of one of the bones; that is, the disease is localized and the symptoms are merely those of a dull aching pain. In the more malignant type it begins in the synovial tissue or the surrounding soft tissues. In this form the infection spreads widely by direct extension. This is the inflammatory type which gradually involves one or more of the bones and presents early the clinical signs and symptoms of inflammation.

In their summary they state that amputation through the middle third of the lower leg is indicated in advanced cases in which the disease is widespread in both tarsal and metatarsal bones and surrounding soft tissue. Isolated lesions of the toes are best treated by amputation. Excision is indicated in any case in which the disease is localized sufficiently so that even though the diseased area is removed entirely a useful portion of the foot will remain. The same methods are particularly adaptable to the adult.

TUBERCULOSIS OF THE SHOULDER

There are two types of tuberculosis of the region the first of which is described as *arres siccus*. This is the dry type and the one most amenable to treatment. The second is the *fungous* or *fulminans* form. This latter is less suitable for operative treatment. In type I arthrodesis is indicated at any stage in any individual past the age of fifteen years. Prior to that time conservative therapy may result favorably. In the fungous type it may be necessary to resect the shoulder joint since it is frequently complicated by pulmonary changes. Because of this the prognosis is necessarily poor.

TUBERCULOSIS OF THE ELBOW

Fortunately lesions of this joint usually occur only during adult life. During childhood synovial tuberculosis is occasionally observed and is characterized by a thickening of the synovium with formation of *rice bodies* and villi. This type is amenable to conservative therapy.

The osseous group that is that form most frequently found after the age of fifteen years, tends to break down rather quickly and unfortunately is frequently associated with pulmonary lesions. Because of this the prognosis is poor. If however the pulmonary lesions can be successfully treated then operation in the form of an arthrodesis is to be recommended. In severe cases either resection of the elbow or amputation are the methods employed, resection being performed in the intermediate group and amputation in the more advanced.

TUBERCULOSIS OF THE WRIST

Conservative therapy should be resorted to less frequently in this type because of the fact that the wrist joint is composed of a series of small bones which normally exhibit poor healing. Furthermore since conservative therapy has of necessity to be very much more prolonged it results in a very badly functioning limb. Bearing these facts in mind operation is indicated early and can be successfully performed in children as well as adults. Total resection of the wrist is far superior to partial resection. Bone grafting operations may be resorted to in the milder cases whereas in severe ones with

sinus infection and destruction amputation is the method of choice

Denms and Jean in 1937 published a paper in which they cited cases in which operation previously had been done by Ollier and they were able to trace the results of twenty eight of thirty nine resections which had been performed many years before. Of these patients fourteen were still living and were re examined for periods ranging up to fifty three years after resection. In all the surviving patients the results were good.

TUBERCULOSIS OF THE SHAFTS OF LONG BONES

Hsieh Miltner and Chang observed thirty eight patients with tuberculosis of the shafts of the large bones of the extremities during a period of eleven years between 1921 and 1937 this total representing 4.8 per cent of 786 cases of bone and joint tuberculosis treated during the same period of time. This is a large percentage and far exceeds that noted in any other clinic. In fact tuberculosis of the shafts of the bones is uncommon in the United States and Continental Europe. They divided the lesions into four types according to the roentgenographic appearance.

Type 1 *Tuberculosis perostitis* This is the rarest of all forms of shaft tuberculosis.

Type 2 *Solitary tuberculous abscess* represents Brdies type.

Type 3 *Local tuberculous osteomyelitis* results in a fairly extensive involvement of the shaft. Later in the disease after abscesses have developed externally the roentgenographic findings are frequently very confusing because of the added factor of infection which usually stimulates the formation of an involucrum.

Type 4 *Mass tuberculous osteomyelitis*

A patient with shaft and active pulmonary lesions did not respond favorably to treatment. This observation is similar to that of Cleveland and others. It is their belief that amputation of the affected limb is strongly indicated in these cases.

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for it completely eradicates the active peripheral focus and allows of a greater opportunity for the control of the visceral lesions. Approximately 75 per cent of the uncomplicated cases respond favorably to the operative treatment of wide excision of both the diseased bone and soft tissue with primary closure and immobilization in plaster. In those instances in which there was sufficient discharge the Orr treatment was employed in much the same way as in pyogenic osteomyelitis.

CONCLUSIONS

Tuberculosis of bones and joints is amenable to surgical therapy in the absence of complications such as visceral or metastatic involvement. Surgery is also best resorted to for economic reasons after the age of fifteen years in older people. Limb ablation may save life and lessen toemia. Surgery tends to reduce the period of hospitalization and the danger of recurrence. It must be stated however that surgery is merely an adjunct to conservative therapy when properly applied.

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THE TREATMENT OF CHRONIC OSTEOMYELITIS

JOSEPH BUCHMAN M.D. F.A.C.S.†

HISTORICAL APPROACH

THE history of osteomyelitis is exceedingly involved and cannot be considered in detail in an article of this size. It is of interest however to mention briefly the evolution of the therapy of this condition. Hippocrates (350 B.C.) recognized the frequency of bone infections in compound fractures and advised against the probing of such wounds to avoid pus formation. He also recognized the occurrence of sequestra and advised their removal. Draining sinuses were treated by him with applications of antiseptic solutions of wine and spices. Little further progress was made until the time of Pare (sixteenth century) who recognized diseased bone and frequently treated severe cases by amputation. Generally however the treatment of these wounds in Pare's time consisted of all manner of applications some of them very repulsive such as crushed birds lice incinerated toads powders made from Egyptian mummies. Oriental herbs boiling oil mixtures of yolk of eggs or oil of roses and turpentine. The variety of these mixtures was without number. Another highly interesting value at that time consisted of treating the offending wound on causing the injury with these concoctions while the wounds were merely washed and dressed. Still others applied the remedies to the localized thing rather than to the wound.

The first beginning of progress came with the eighteenth century when John Hunter and John Hunter wrote extensively upon bone growth and bone disease but added little to its

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therapy. During the early part of that century gross resection of bone shafts was sporadically practiced but amputation was still the popular mode of therapy. Towards the latter part of the eighteenth and the early part of the nineteenth century extensive excision of bone shafts and at times almost complete removal of bones became the universal practice in Germany, England, France and the United States. The etiology of osteomyelitis was not recognized until the time of Pasteur and Lister.

In the latter half of the nineteenth century the Germans differentiated between the *acute* and the *chronic* form of osteomyelitis, the latter still being classed as a chronic disease of bone while the former was spoken of as osteomyelitis *acuta spontanea*. The first really significant study of acute osteomyelitis was that of Leier in 1894. The chronic form was divided into two types, one following the acute form and the other following gunshot wound or compound fractures. The differentiation of chronic osteomyelitis from tuberculosis of bones did not occur until after the isolation of the specific bacterium by Koch in 1886. With the beginning of the development of roentgenography in 1883, earlier recognition of this affection became possible with resultant earlier and less extensive surgery.

It is very evident from the above resume that the treatment of chronic osteomyelitis has been haphazard up to recent times. The surgical therapy varied from extensive excision of bone shafts to mere incision and drainage and removal of sequestra. The problem of filling the resulting bone cavities gave rise to the development of various bony and synthetic plastic operations and the use of various plastic and solid substances and even plaster of Paris. All of these procedures have been met with little success.

The really significant advances in the therapy of chronic osteomyelitis were made during the first World War and thereafter as a result of observations and lessons learned during that titanic struggle. The Currel Dakin method (thymol, bismuth iodoforn and paraffin paste) and the Orr technique were instituted and practiced during the war Maggot therapy

the result of the first World War observations was introduced and perfected about a decade thereafter. These procedures with various modifications form the backbone of the modern therapy of chronic osteomyelitis.

PATHOLOGY

Before attempting the evaluation and the description of these various techniques it is essential that the local pathological lesion should be clearly understood. One should visualize a diseased bone which has undergone changes during the processes of destruction and of ineffectual attempts at healing. The bone has lost its smooth contour and normal shape and its cortex is thickened and sclerosed as a result of subperiosteal new bone or involucrum formation. The medullary canal is usually obliterated by newly deposited dense bone and the haversian canals are narrowed as a result of endosteal proliferation. This newly formed bone which is poorly nourished and therefore unable to resist infection represents the ineffectual attempts at repair.

The processes of destruction are represented by the presence of variously shaped and sized cavities within this dense bony scar containing frank pus, infected or indolent granulation tissue, avascular necrotic fibrous tissue and necrotic bone sequestra. There may also be found areas of atrophic bone with fibrous marrow tissue. This may be accompanied by cloaca and sinus formations. The covering periosteum is thickened and fibrous, poorly nourished and densely adherent to the roughened bone. The soft tissue cloak of such a bone usually presents areas that are densely cicatrized and poorly nourished as a result of long standing stasis of blood and lymph incidental to the chronic inflammatory process, sinus tracts, previous operative procedures and long periods of immobilization.

The permanent cure of such a lesion is because of the very nature of the lesion (the disseminated foci enclosed within the bone) most difficult and hitherto only infrequently attained. Those fortunate instances which have remained healed for long periods of time present on roentgenographic

examination a completely reformed bone normal in shape and contour with patent medullary canal and absence of the characteristic areas of sclerosis and rarefaction. In these parts the scar has been reduced to a minimum and the blood and lymph supply has been restored to a maximum.

BASIC SURGICAL ATTACK

It becomes evident that in order to obtain effectual healing a *complete* excision of the diseased and scarred tissue is essential. This desideratum under the best of circumstances may not always be attainable even in those areas which are readily approached surgically because it may not be possible to eradicate all diseased areas and the surgeon may not be able to decide whether or not all of the minute foci have been removed from the entire periphery of the bone. Nevertheless it is now the consensus that an attempt at complete removal of diseased bone and scarred tissues should be made wherever feasible. Mere removal of sequestra and inter drainage of bone cavities only temporary and are generally considered insufficient.

The surgical attack is best performed wherever possible under tourniquet control. The incision should be liberal and should allow the most direct approach to the diseased area without endangering important blood vessels, nerves and muscle mechanisms such as the extensor apparatus of the knee or elbow. The soft tissue scar should be excised. The periosteum and soft tissues should not be stripped from the bone beyond the limits of the area it is proposed to excise. A wide trough is then made in the long axis of the bone extending from normal bone above to normal bone below exposing involved medullary canal or metaphysis at each end. The walls of this trough are leveled off to make a shallow cavity. All visible foci and overhanging shelves are removed. Careful consideration must be given to leave sufficient bone to maintain the continuity of the affected bone. The wound is then thoroughly flushed with hot saline solution to remove all bone debris and to control oozing. The wound is then packed with dressings and immobilized in a manner dependent upon the technique which will be used in the after care of the lesion.

THE PROBLEM OF CLOSURE OF THE WOUND CAVITY

The problem of closure of the usually large rigid walled cavity resulting from the previously described surgical procedure has been a stumbling block from the days extensive surgical therapy became possible. The various muscle plastic operations were usually doomed to failure because the wound were practically without exception sufficiently infected to prevent primary healing. Furthermore if primary healing did occur the resultant fibrous replacement of the transplanted muscle flap would leave a scar which would readily break down. Similarly secondary closures subsequent to the appearance of healthy granulations throughout the wound usually break down even if temporarily successful for the reason that there is always a sufficient amount of infection in such wounds to preclude healing under such circumstances.

It therefore becomes apparent that the most satisfactory results could be obtained only by the filling of the wound with healthy granulation tissue from the bottom up to complete closure. Unfortunately the growth of granulation tissue proceeds satisfactorily up to a certain point subsequent to which the growth becomes unequal in various parts of the wound indolent and unduly prolonged. Healing finally comes to a standstill resulting in the formation of sinuses and failure of closure of the wound. This is due to the gradual conversion of the aging granulation tissue at the periphery of the wound into fibrous tissue resulting in the shutting off of the blood supply as is characteristic of the formation of scar tissue. Hence it becomes self evident that in order to obtain satisfactory healing the granulation tissue should proliferate with sufficient rapidity to fill the entire cavity before the blood supply is shut off by cicatrization. This *time factor* is to my mind of utmost importance in the satisfactory healing of osteomyelitic wound.

In addition to blood supply there are other factors which influence the speed of growth of granulation tissue. The presence of diseased necrotic and sloughing tissues the presence of foreign bodies and the presence of infecting micro-organisms are all deterrents to rapid growth. Furthermore the intro-

duction into the wound of various chemicals for the purpose of sterilization is often a deterrent to rapid growth

CRITERIA FOR SUCCESSFUL THERAPY

In view of the foregoing considerations an ideal system of therapy of chronic osteomyelitis should provide for

- (1) a thorough surgical removal of all diseased and sequestered tissues as well as any foreign bodies that may be present
- (2) an efficient method of removal of wound discharges and of sloughed off tissues that occur subsequent to such an operation
- (3) an efficient and harmless method of disinfection of the surgically formed wound and
- (4) an agent that would produce even and rapid filling of the wound with healthy granulations at a sufficient rate of speed to completely fill the cavity before the circulatory changes incidental to scar formation occur

These criteria provide a basis for a rational analysis of the various techniques commonly used in the therapy of chronic osteomyelitis. All of these methods provide for a thorough surgical attack in all suitable instances.

CARREL DAKIN TREATMENT

In the Carrel Dakin and kindred method fine soft rubber tubes with one end tied off and perforations in the periphery near this end are so placed in the wound as to reach all of its crevices. Layers of vaseline gauze are then placed over the margins of the wound which is then filled with a voluminous dry gauze dressing through which the open end of the tubes project. After a forty eight hour interval subsequent to the operation Dakin's solution or its modification is instilled through these tubes at frequent intervals usually every two hours. The entire dressing is changed daily. The early dressings are painful and often require anesthetics. These dressings are repeated till healing occurs or failure becomes evident.

At the time of the introduction of this method it was thought possible to sterilize and cure by such antiseptic therapy and thus promote healing. It has since been realized that

sterilization of wounds by chemicals is not usually feasible. Mild antiseptics suitable for such purposes are in a measure specific in their action thus precluding the use of a universal drug. The limit of tissue penetration of most antiseptics is very small thus precluding any effect upon micro organisms deep to the superficial layers of the wound. The use of potent antiseptics is deleterious to the host tissues while the use of mild antiseptics is ineffective on the more resistant bacteria which eventually give rise to strains which remain unaffected in the presence of the antiseptic. Furthermore the more potent the antiseptic the more certain is its destruction of leukocytes which through their phagocytic activities form the defense mechanism of the body.

This method therefore meets only two of the four criteria proposed for the ideal approach to the therapy of chronic osteomyelitis namely the thorough surgical removal of all diseased tissues and the removal of wound slough and discharges. Clinically the method often requires repeated anesthesias inflicts considerable pain and introduces secondary infections by repeated dressings and makes life tedious for the ward surgeon. The Carrel Dakin method is an improvement over the previous techniques but the frequency of failures of healing and the frequency of recurrences remain so high that the procedure has gradually lost its popularity.

ORR TREATMENT

The Orr technique like the other methods under consideration is based upon a thorough saucerization operation at the completion of which the wound is swabbed with 10 per cent iodine followed by 95 per cent alcohol. More recent usage omits the use of the iodine and alcohol. The wound is packed wide open with gauze well impregnated with vaseline. This is covered with dry gauze and the limb is thoroughly immobilized in a circular plaster of paris bandage. Subsequent dressings should be infrequent at four to six week intervals under sterile conditions with repetitions of the described technique.

The vaseline pack acts as an efficient drain and by its resistance permits an evenly distributed growth of granulations

from the bottom up. The nonadherence of the pack allows it to be pushed out of the wound by the newly formed granulations. The infrequency of the dressings avoid the accompanying incidental secondary infections, pain and discomfort. The immobilization provides relief of muscle spasm and in lessening the inflammatory process and relieves pain. Spontaneous disinfection of the wound is thought to occur on the basis of the explanations and theories advanced by Besredka and d'Herelle through the formation of bacteriophage.

It is therefore evident that the Orr technique fulfills only three of the four criteria for the ideal therapy for chronic osteomyelitis, namely, the thorough surgical removal of all diseased tissues, the efficient drainage of wound sloughs and discharges and a harmless method of spontaneous and therefore possibly uncertain disinfection of the wound through the formation of the bacteriophage. This method does not provide, apart from the natural processes of repair, for the hastening of the formation of granulation tissue to fill the cavity before cicatrization occurs. Nevertheless this method is much superior to the Carrel-Dakin technique in that it is more effective, the persistence of sinuses and failure of healing are less frequent, it is more easily applied, it is less distressing to the patient and less toilsome to the surgeon.

This method is not entirely satisfactory in that there are still a considerable number of failures of healing and recurrences. The odor incidental to the infrequent dressings is at times distressing. Furthermore the loss of motion in adjacent joints incidental to the prolonged immobilization is at times disabling. Notwithstanding all this it is the most frequently used method at this time. Under war conditions it has proved effective as was indicated by Trueta's work.

Modified Orr Method

Albee—The Orr method has been modified by Albee to the extent that he introduces into the wound a bacteriophage potent for the offending organism. The wound is packed with a varying mixture of paraffin and vaseline depending upon the depth of the cavity. This mixture is introduced into the wound in the melted state at about 110° F. When it cools and

hardens it fills the crevices and keeps the soft parts apart. A rubber catheter is then inserted through this paraffin vaseline tampon to the bottom of the cavity for the subsequent injection of bacteriophage. The increased efficacy of this modification does not appear to be confirmed in the literature.

Lohr—Another modification of the Orr method is that of Lohr who replaces the vaseline gauze pack with a *cod liver oil pack*. This modification does not appear to alter the principles underlying the method save for the addition of the great wealth of vitamins and the healing properties said to be inherent in the cod liver oil.

THE BIPP METHOD

The bipp (bismuth iodoform and paraffin paste) method which is said to have been introduced by Rutherford Morrison prior to the Orr method is essentially similar to the Orr method. It differs in that the wound resulting from the operative procedure is washed out with alcohol in order to dehydrate the surface tissues. No more than 2 drams of bipp paste which consists of 1 part bismuth subnitrate with 2 parts of iodoform powder and sufficient liquid paraffin to form the paste is rubbed into and made adherent to the walls and crevices of the wound. The wound is then packed with soft gauze soaked with liquid paraffin containing a little bipp and the part is immobilized either in plaster of paris or by other methods of splinting.

Morrison's aim was to institute curtain drainage by means of a thin film of liquid paraffin adherent to the surface of the wound. To make this possible he compounded this paste the virtues of which aside from making possible the physical adherence of the liquid paraffin are said to lie in the fact that the bismuth subnitrate is comparatively harmless and that the iodoform though devoid of bactericidal powers has been traditionally thought to inhibit the growth of bacteria.

The only difference between the Orr and the bipp methods is according to the proponents of the latter technique a substitution in the former of vaseline for liquid paraffin and that of bismuth and iodoform by a disagreeable odor. One must

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food. Maggots therefore prepare their food for consumption by secreting a proteolytic enzyme which acts on the dead protein matter in the medium to break it down to a liquid state. This act of feeding results in the removal from the wound of sloughed and necrosed tissues, thus removing the medium upon which bacteria grow. In this act of feeding many microorganisms are consumed and destroyed by a bactericidal substance which is produced in the alimentary tract of the maggots. This substance has also been demonstrated in the excreta of the maggots and has been found lethal for many species of bacteria including *Staphylococcus aureus*, *Streptococcus hemolyticus* and *Clostridium welchii*. The excreta of maggots contain yet another substance, allantoin, which has been found to be a biological stimulant of growth of granulation tissue.

Another characteristic of maggots is that they in some way change the medium in which they live from faintly acid to faintly alkaline, thus further inhibiting bacterial growth.

Yet another characteristic of maggots that is most important to wounds housing them is their continuous crawling about. If the maggots are not excessive in number, the resultant irritation will be sufficiently subminimal to stimulate the rapid formation of granulation tissue. An additional response on the part of the host to this physical irritation is to produce a profuse exudate which aids in washing microorganisms out of the crevices of the wound. This fluid, together with the excess liquid end products resulting from the proteolytic activity of maggots, is drained off in the toilet of the wound with the ultimate result that the wound is thoroughly cleansed physically of debris and bacteria.

It therefore becomes evident that the use of maggot therapy comprises an armada of forces which is found in no other system of therapy. It includes (1) the use of subminimal physical irritation to induce rapid formation of granulation tissue, (2) the use of subminimal physical irritation to produce a profuse exudate which aids physically in cleanse the wound and its crevices of bacteria and debris, (3) the use of enzymatic digestion of necrotic tissue to cleanse the wound and thus eliminate the medium upon which bacteria grow, (4) the use of enzymatic digestion of necrotic tissue to produce lique-

however caution against the use of more than 2 drams of this paste at one time lest toxic symptoms occur

MAGGOT THERAPY

The preparation of the part for maggot therapy consists of shaving and cleansing with soap and water. No chemical disinfectants need be used at any time prior to or at the time of the operation. The surgical procedure must be as thorough as in the hereinbefore described systems of therapy for the maggot will not do what the surgeon fails to do. At the conclusion of the operation the wound is lined with vaseline gauze and packed with plain gauze. A voluminous compression bandage of sheet wadding flannel and adhesive is then applied. No plaster of paris support need be used unless a fracture of the part is feared. After seven to ten days the packing is gently removed. This is usually painless and bloodless because of the vaseline gauze lining.

A suitable number of maggots vary from several hundred to a thousand depending upon the size of the lesion are then transferred to the wound. This is accomplished by adding sterile saline to the flask containing the larvae. The flask is shaken to make a suspension which is filtered through a small square of fine meshed sterile cheese cloth. The cloth and its superimposed maggots are then placed in the wound. The skin at the periphery of the wound is smeared with liquid adhesive and a piece of fine meshed sterile cheese cloth of appropriate pattern is placed over the wound and made adherent to its periphery. This results in a very effective cage for the maggots.

The frequency of subsequent maggot dressings will depend on the longevity of the larvae. This in turn will vary directly with the amount of slough and discharge present. At the outset dressings should be done every five days. Subsequently as the wound diminishes in size and its cleanliness increases the dressings should be more frequent. Dressings should be continued until the wound becomes obliterated.

The effectiveness of maggots in properly selected wounds is closely tied to their normal life processes. The alimentary tracts are so constituted that they can consume only liquid

sclerosis and rarefaction disappear. In those instances in which further operative procedures were instituted for one reason or another the gross appearance of these healed areas were most satisfactory in that the bone had lost the hardness and avascularity characteristic of the chronic osteomyelitis. The frequency of failure of healing, persistence of sinuses and recurrences in those instances in which a thorough and complete operative procedure could and actually was satisfactorily performed is relatively small. The results in those instances which could not be subjected to a thorough surgical attack either because of anatomic considerations or because of other contraindications are as unsatisfactory as with other methods.

Maggot therapy has in my experience produced the most satisfactory results obtainable at the present time. Its greatest deterrent is the considerable *expense* incurred in the use of commercially produced maggots and in the relatively long periods of hospitalization. The first element of the cost can be considerably reduced by an efficient hospital laboratory where maggots may be bred inexpensively. The second element of expense becomes insignificant when one notes on comparing with other methods the relatively short period of convalescence, the infrequency of recurrences in properly selected and properly treated cases, the lack of limitation of motion in adjacent joints and the relative well being of the patients while undergoing this form of treatment.

Attempts have been made to substitute for maggot therapy by the use of allantoin, urea and maggot enzymes. All of these products substitute for but one of the many virtues of maggots. The most important characteristic, the ability to produce subminimal physical irritation to hasten the formation of granulation tissue, has not been reproduced by any of the attempted shortcuts. None of the substitutes has been proved to be effective.

SULFATHIAZOLE THERAPY

This discussion of the local therapy of chronic osteomyelitis would be incomplete without calling attention to the most recently described but as yet unproved method of treatment. This plan of therapy described by Dickson, Diveley and

faction which aids in the physical cleansing of the wound of bacteria and debris (5) the use of a potent bactericidal substance in the alimentary tract of the larvae and in the surrounding medium to destroy the offending micro organisms (6) the use of chemical inhibition of bacterial growth through the change of the reaction of the medium from acid to alkaline and finally (7) the use of a biological stimulant of growth through the formation of allantoin

Maggot therapy fulfills all of the criteria proposed for the ideal method of treatment of chronic osteomyelitis in that (1) it is postulated on a thorough surgical removal of all diseased and scarred tissues as well as all foreign bodies present (2) it provides an efficient method of drainage (3) it provides an efficient and harmless method of disinfection of the wound and finally (4) it provides an agent which hastens the rapid filling of the wound with healthy granulations at a sufficient rate of speed if the method is properly used to completely fill the cavity before the circulatory changes incidental to scar formation occur

Clinically wounds housing maggots undergo rapid and striking changes. Soon after the introduction of this therapeutic agent there is a profuse exudate which persists during the lifetime of the maggots. The acid reaction of the osteomyelitic lesion becomes alkaline. All sloughs and necrotic material disappear to be replaced by rapidly developing firm and healthy granulations. Bacterial counts show a rapid diminution in the number of micro organisms in the wound. Complete closure of the wound occurs in two to four months depending upon a number of variables such as the age of the patient the chronicity of the lesion the extent of the lesion the number of previous operations the general status of the blood and lymph circulation of the part and the frequency of maggot dressings

The resultant scars are usually soft and nonadherent and the adjacent joints are not bound down by intrinsic adhesions or by adhesions of their activating muscular mechanisms. The bony scars as visualized on the roentgenogram are minimal for the medullary canals become reformed the bone contours assume more normal aspects and the characteristic patches of

sclerosis and rarefaction disappear. In those instances in which further operative procedures were instituted for one reason or another the gross appearance of these healed areas were most satisfactory in that the bone had lost the hardness and avascularity characteristic of the chronic osteomyelitis. The frequency of failure of healing, persistence of sinuses and recurrences in those instances in which a thorough and complete operative procedure could and actually was satisfactorily performed is relatively small. The results in those instances which could not be subjected to a thorough surgical attack either because of anatomic considerations or because of other contraindications are as unsatisfactory as with other methods.

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OTHER CONSIDERATIONS IN TREATMENT

The modes of therapy hereinbefore discussed represent the more modern approaches in the care of the local lesion. One must not however overlook the *systemic* aspect in the treatment of chronic osteomyelitis. This should obviously include a high vitamin high caloric diet and proper hygienic care. In the presence of secondary anemia leucatinics liver therapy and transfusions should be administered. Aside from these general measures little can be done for there are as yet no available anti septic drug or sera effective in the local lesion. Vaccine bacteriophage and other methods all in turn have been found useless insofar as the local lesion in the usual case of chronic osteomyelitis is concerned. The use of the sulfone drugs either with or without primary amine is still in the experimental stage and judgment of their effect must therefore be left in abeyance for the present.

It should not be assumed that the treatment of chronic osteomyelitis is as simple as the *unary* may let it be believed from a perusal of this present treatise. There are many aspects of the disease which could not readily be discussed in the limited space allotted. Furthermore there is a considerable group of

patients suffering from chronic osteomyelitis who because of the anatomic location of the disease cannot be submitted to the radical operation postulated in the various types of therapy described. In these incision for drainage may be all that can be accomplished. In some persistently draining sinuses may be by the very nature of the situation acceptable while in others amputation may be desirable and even mandatory. Few cases of chronic osteomyelitis can be effectively treated by rote. Skill and good judgment based on a critical experience rather than the mere repetition of previous errors are essential to the armamentarium of the surgeon who seriously undertakes the therapy of this dread affection.

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APONEUROSIS OVERLAP FOR THE CURE OF INGUINAL HERNIA

HENRY F. GRAHAM, M.D., F.A.C.S.

and

EDGAR O. MARTINSON, M.D.

It is easy to cure the ordinary inguinal hernia if a good overlap of the aponeurosis of the external oblique muscle can be obtained. If overlap is impossible a sheet of fascia lata from the thigh should be sutured over the opening.

No elaborate bag of tricks is necessary for this condition.

In January 1933 Meynen published a description of the method he used but made no claim for priority. His operation seemed so simple and logical that we abandoned the Bassini operation and adopted it for practically all our inguinal hernias. In the six year period from January 1933 to January 1939 747 inguinal herniorrhaphies on 199 patients have been performed by this technic on the First Surgical Service of the Methodist Hospital. Sixteen of these operations were for recurrent hernia and eleven were for strangulated hernia. Twenty-four were for direct hernia.

Examinations have been made of 61 of these patients (81 per cent) from one to five years after the operation. One hundred and twenty-six have been followed more than two years. There have been four recurrences in those examined (7 per cent).

The details of technic and the care used in such an operation determine the end result more than the brilliance and manual dexterity of the operator. These operations were performed by twenty-seven different surgeons.

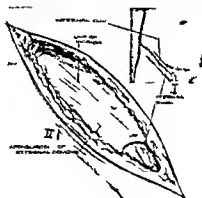
TECHNIC

The incision starts 1 inch above and to the inner side of the internal ring. It is prolonged obliquely downward and in

ward to a point over the pubic bone 1 inch below the external ring.

Towels are clipped in place to cover the skin completely. Severed vessels are ligated and the outer surface of the aponeurosis is scraped clean with the edge of a scalpel, removing all fat and areolar tissue from an area 1 inch wide that will later lie in apposition to the inner surface of the lower flap.

The incision in the aponeurosis is parallel to Poupart's ligament, ending close to the inner pillar of the external ring. This makes a wide flap below. No separation is made between the



F 151-J t h k H I l p w III
L fl p IV D d d ar d fir k f V f ru
mpl d Ed f p k f V S l f ru
pl d

aponeurosis and the internal oblique and transversalis muscles. The spermatic cord is then lifted up, the hernial sac is separated, located high up and removed. Excess fat and cremaster muscle are taken away. All fat and areolar tissues are carefully cleaned off the floor of the external ring and the adjacent pubic periosteum.

Next the edge of the upper and inner flap is sutured to Poupart's ligament with Pagenstecher suture, placing the stitches $\frac{1}{2}$ or $\frac{3}{8}$ inch apart.

The first suture unit is the inner pillar to the pericent of the pubic bone. At the internal opening sutures are tightly

tied on both sides close to the cord and the edge of the aponeurosis is cut with scissors to give a triangular opening around the cord which fits snugly without pinching. The

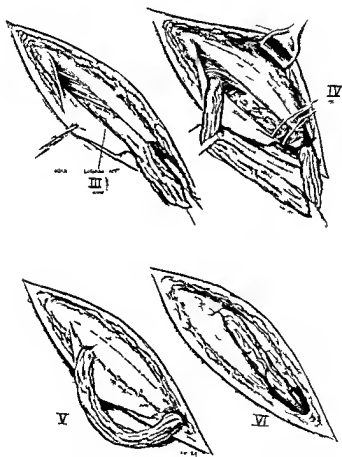


Fig. 151 (C) d)

inner surface of the lower and outer aponeurotic flap is then cleaned and brought up and sutured to the outer surface of the upper and inner flap with Pagenstecher sutures. This

ward to a point over the pubic bone 1 inch below the external ring

Towels are clipped in place to cover the skin completely. Severed vessels are ligated and the outer surface of the aponeurosis is scraped clean with the edge of a scalpel removing all fat and areolar tissue from an area 1 inch wide that will later lie in apposition to the inner surface of the lower flap.

The incision in the aponeurosis is parallel to Poupart's ligament ending close to the inner pillar of the external ring. This makes a wide flap below. No separation is made between the

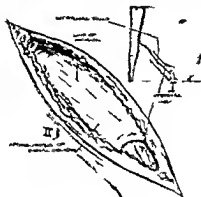


Fig. 151—1. f. as h. lin. II. I. h. po. on. III.
Low fl. p. IV. D. d. d. ar. d. hrs. co. es. V. F. rs. ro. f. sutu. es.
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pl. d.

aponeurosis and the internal oblique and transversalis muscle. The spermatic cord is then lifted up, the hernial sac is separated, ligated high up and removed. Excess fat and cremaster muscle are taken away. All fat and areolar tissues are carefully cleaned off the floor of the external ring and the adjacent pubic periosteum.

Next the edge of the upper and inner flap is sutured to Poupart's ligament with Pagenstecher sutures, placing the stitches 1/2 or 3/4 inch apart.

The first suture unites the inner pillar to the periosteum of the pubic bone. At the internal opening sutures are tightly

ried on both sides close to the cord and the edge of the aponeurosis is cut with scissors to give a triangular opening around the cord which fits snugly without pinching. The

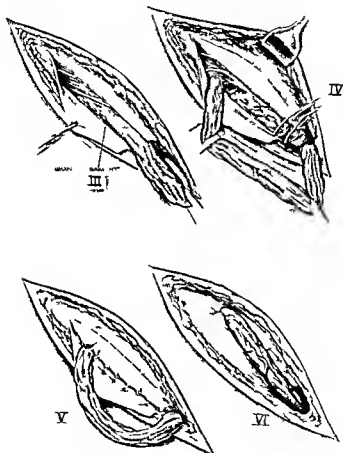


Fig 151 (C + D)

inner surface of the lower and outer aponeurotic flap is then cleaned and brought up and sutured to the outer surface of the upper and inner flap with Pirostcher sutures. This

makes two right angle turns in the cord and transplants it to a new canal beneath the fat layer. Interrupted plain gut sutures in the fat and a continuous skin suture complete the operation.

No bridge or special support for the scrotum is necessary unless bleeding is feared.

Important points in the technic are

1 Removal of all areolar tissue from adjacent surfaces

Removal of all fat and muscle that can shrink later and leave an opening at the internal or external rings

3 Nicking the edge of the aponeurosis opposite the cord. This permits a tight fit without pinching

4 The use of nonabsorbable sutures resulting in less tissue irritation and a softer less indurated wound

The end result will depend upon the character of the aponeurosis and the meticulous efforts of the surgeon

COMPLICATIONS—There have been no deaths in the series. Complete atrophy of the testicle occurred six times, two after attempts to bring down an undescended testicle. Five instances of partial atrophy were noted. No atrophy has been seen in any of our recent cases since we began nicking the edge of the aponeurosis to make a triangular opening instead of a slit.

Hydrocele occurred five times. In three of these an associated excision of a varicocele was performed in addition to the herniorrhaphy.

Two of the recurrences came two months after a bilateral herniorrhaphy. The patient was alcoholic and had a chronic bronchitis.

Spinal anesthesia was used one hundred times.

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USE OF X RADIATION AS AN ANALGESIC AGENT

JOHN RUSSELL CARTY M.D. F.A.C.R.

ACTION OF X RAYS IN THE RELIEF OF PAIN

THE action of x rays in the relief of pain is poorly understood. It is probably based on several different actions. It is known by clinical experience that roentgen radiation often has a beneficial effect upon inflammatory processes. The most likely theory postulates a leukocytic destruction with the liberation of antibacterial substances. There is no convincing evidence that there is a direct effect of the radiation upon bacteria themselves especially under conditions prevailing in the human body. Thus actually the anti-infectious quality of the roentgen ray probably accounts for the relief of pain where there is an infection. This comprises in all probability a large group of cases. Where malignancy is involved a relief of pressure due to the reduction in size of the tumor mass may play a large part. However there are cases in which pain is relieved without this reduction in size.

Lillsberg, Davidoff and Dyke, Carty and Ray have shown that large intensities of radiation applied to the brain cause cytotoxicity. Possibly there may be an alteration in the function of a nerve. Vascular action may also play a part.

In a few instances roentgen therapy may actually increase the pain. A study of ten such cases on autopsy findings showed that in six there was definite infiltration of the nerve tissues by cancer cells and in the remaining four cases there was a great deal of fibrosis. The role of fibrosis in producing this effect is not clear as the pain of certain scars may be greatly relieved by roentgen therapy.

SELECTION OF CASES

It should be borne in mind that roentgen therapy is a powerful agent and should not be used indiscriminately. There

fore it is necessary to make a critical selection of cases in order that vague pains on a neurotic basis be excluded. If this is not done the method may be discredited. Our criteria are as follows:

1. Definite clinical signs of pain such as lack of sleep
2. Localization of the pain in one general area
3. Sensory changes or local tenderness
4. Evidence of inflammation
5. Evidence of tumor formation

In the long standing cases x-ray radiation should be reserved for instances in which other generally accepted methods have failed.

If a case is deemed suitable for x-ray therapy the following considerations may be of help in estimating efficacy of the method:

1. Age is important. Everything else being the same a much better result could be obtained in a patient twenty years of age than one sixty years old.

The earlier treatments are given in the course of the disease the better the result would be.

3. If there is an exacerbation of pain immediately following the first few treatments a good result may confidently be looked for.

4. If no relief is obtained during or immediately following an adequate series of treatments the treatment will probably not meet with success.

5. An adequate amount of radiation must be given.

The use of x-ray therapy for the relief of pain in *malignant conditions* is perhaps not sufficiently appreciated. X-ray therapy is well worth considering unless there is some definite contraindication such as the terminal stage of the disease or markedly depleted blood even though the tumor may be radioresistant. Relief of pain will follow in some instances even though not much change is noted in the growth of the cancer.

The intensity and duration of pain in *superficial infections* may some times be considerably reduced. The x-ray acting as an efficient and rapid poultice. Painful infections such as *boils* and *carbuncles* following intramuscular injections are well

suited for x ray therapy. They should always be treated with the active cooperation of the surgeon. It is very important not to give too large a single dose as there is clinical evidence to indicate that large doses may actually spread the infection. Not more than 100 roentgen units should be given at one time in an acute infectious process. Painful infections of the *parotid gland* respond well particularly if there is no evidence of dilation of the ducts due to fibrosis or stone. It is well to make sialograms in all cases with the possible exception of acute surgical parotitis.

Other uses of x radiation as an anesthetic agent are described in the case reports given later.

In addition to the conditions mentioned x ray has been used in the treatment of *anginal pain*. Our experience is too limited to permit the drawing of conclusions.

TECHNICAL CONSIDERATIONS

In most instances we prefer to use 00 KVP radiation filtered with 1 to 2 mm of copper plus 1 mm of aluminum. Analgesia to a varying degree will be usually produced by a total dosage of 100 to 1000 roentgen units measured in air to the skin depending upon the causative factor. Acute infections require 100 to 600 roentgens. Herpes zoster and acute bursitis usually require at least 800 roentgens. Pain due to deep seated cancer obviously requires more radiation per area up to 2000 roentgens or more before results are obtained.

In general *multiple small doses* are preferred to a large single dose. As has been mentioned this is definitely the case in acute infections. If the treatment has been insufficient there is a greater tendency to a subsequent recurrence. In herpes and radiculitis burning, itching and tingling sensations may persist for several months following the relief of the pain. Recurrence is apt to take place if patient shows these symptoms.

Caution must be exercised to prevent the application over the radiated area of heat in any form, adhesive plaster, irritant ointments and the like. These may sensitize the skin with a resultant unexpectedly severe reaction.

The question of repeating the series for recurrence is a

difficult one. Obviously one cannot continue x radiation indefinitely. Whether or not the series should be repeated depends upon the seriousness of the pain and the amount previously given. No definite rules can be laid down regarding this. Each case must be considered by itself.

ILLUSTRATIVE CASES

Case 1. Polyarthralgia of the Right Elbow

History—A woman twenty-eight years of age complained of pain in the lateral aspect of the right elbow joint and was referred for roentgenography. Two years ago the patient who is a telephone operator injured her right elbow slightly while opening a window. Since then she has had occasional twinges of pain which became more frequent. Few days ago she had a very severe attack of pain with inability to move the right elbow and swell on the lateral aspect.

Examination—Physical examination was essentially normal except for the local condition. The patient was suffering severe pain. There was tenderness, swelling and heat noted on the lateral aspect of the joint space. Motion of the elbow was almost completely restricted. Palpation was very difficult because of tenderness but in the center of the swollen area there was a small oval area which appeared somewhat hard.

X-ray examination showed no evidence of pathological change within the joint. There was linear shadow of increased density lying just lateral to the central condyle of the humerus. The shadow was completely amorphous and non-calcareous. It was noted in the scapular bone.

Diagnosis—As per arthritic calcium deposits apparently in a ligament.

Plan of Treatment—The patient received six daily treatments of 200 roentgen units (measured in air) per treatment using 00 KVP radiation 50 cm. kV target distance through 1 mm. of copper and 1 mm. of aluminum filtration. The patient returned to expectant observation of the pain and swelling.

Subsequent Course—Shortly after the first treatment the pain became aggravated and the swelling increased markedly. Following the second treatment similar reaction was noted only less marked. Following the third treatment the redness subsided but the tenderness diminished and some motion was possible. The patient had a good night's sleep. The improvement continued.

steadily. Three weeks after the institution of treatment the patient had no pain and was able to move her arm quite freely. Check up radiographs of the elbow showed some decrease in the calcification previously noted.

Six weeks after the institution of therapy the calcified area had disappeared. Aside from a occasional twinge of pain the patient has remained free from distress and is very well satisfied with the result.

Comment—This case represents the most favorable type for the use of x ray therapy in painful peri arthritis in the relatively young age, acuteness of the process, marked immediate reaction to the x ray therapy and disappearance of the calcium deposits.

An unusual feature of this case was the resemblance of the calcium deposit to a piece of bone which might have been detached when the patient injured the elbow two years ago. However the normal neighborhood bone and the behavior under x ray therapy should rule out that possibility. The patient was also instructed to use both hands at the switch board.

Care must be taken not to produce skin changes. In case of recurrence repeat series should only be undertaken with caution. Any dosage under 600 roentgens in some instances is considered insufficient.

Case II: Herpes of the Peroneal Cutaneous Region

History—A fifty four year old Italian woman eight days prior to admission noted pain in the left gluteal region radiating into the posterior and lateral parts of the left thigh. The pain increased gradually, increasing in character gradually increased in severity and accompanied by burning sensation in the same region.

Examination—X ray of the pelvis and lumbosacral spine showed no significant changes.

On physical examination typical herpetic skin lesions were not detected. The distribution of the posterior femoral cutaneous nerve.

Plan of Treatment—Radiation was applied to a 10 by 14 cm field of the left gluteal and sacral plexus at a dosage of 150 roentgens in ten daily fractions of 15 units, using 100 kVp with

111 c pper pl s l mm f aluminum at a 50 cm d tance
 During the course of the treatment the pain disappeared In spite
 of the disappearance of pain the full planned dose was given

Comment—At this age herpes zoster is apt to give rise to chronic postherpetic pain which is exceedingly difficult to treat and may seriously deplete the patients We feel that γ radiation is a powerful prophylaxis in preventing post herpetic pain Once the pain has started however γ radiation is not particularly effective

In certain cases particularly where cutaneous manifestations are marked local treatment is also given One young girl with complete facial herpes associated with marked skin eruption which was erysipeloid in character and threatened involvement of the cornea was treated locally as well as over the ganglion The process cleared rapidly perhaps saving the sight of the affected eye

C III S t e N t

History—J B S a man forty nine year f a s was referred for ray therapy for right sciatic neuritis The seat of the neuritis was the buttocks Following the removal of dental infection the neuritis improved until one month before admission when it became worse There was a history of a previous attack ten years ago

Examination—Physical examination showed tenderness of the spine and right leg to be restricted apparently by pain The pain was a dull aching character tending downwards along the posterior portion of the right thigh to the ankle The legs were definitely tender especially the sciatic trunk There were no sensory or motor neurological changes Radiograph of the spine and pelvis were normal The patient took no analgesics for relief of pain Radiological examination only negative result

Plan of Treatment—Radiation was applied to 10 l x 15 cm field of the lower limb every day at a dose rate of 0.005 cgrs per cm² to a total of 6000 rads in 100 KVP with 1 mm copper filter 1 mm aluminum filter 50 m distance

Comment—The tenderness disappeared following the last treatment There was no exacerbation of pain following the first few treatments Pain slowly stopped and the patient gave up

codeine. Three years later he had no complaints. This represents a good result although the total dosage was somewhat low. The exacerbation of pain following the first treatment is a good prognostic sign.

Case IV Painful Arthritis

History—J. M., a man fifty-five years of age, was referred for x-ray treatment of a painful right shoulder. Pain which was first noted a year ago became steadily worse. Seven months ago the patient had an attack of coronary occlusion confirmed by clinical and laboratory findings. He was unable to sleep because of the shoulder pain and did not wish to take opiates.

Examination—The patient showed the effects of continued pain and lack of sleep. There was limitation of motion of the joint largely because of pain. There was some atrophy of the muscles of the right arm and shoulder.

X-ray examination of the right shoulder showed narrowing of the joint space indicating cartilage destruction with slight productive changes of the subadjacent bone. Diagnosis was hypertrophic arthritis.

Plan of Treatment—Radiation was applied in doses of 700 roentgen units every other day to a total of 1400 units, using 700 kVp with 1 mm. of copper plus 1 mm. of aluminum at 50 cm. distance. Pain and loss of sleep were his most undesirable effect on the cardiac condition. The x-ray treatment was indicated solely to give relief from pain.

Results—Following the third treatment the patient had a good night's sleep.

Radiographs of the right shoulder made three weeks later showed no change. The patient remained free of pain and was free from sleep.

Unrecurrence of the pain after a repeat course of 400 roentgen units was predicted. Before this course was completed the patient died suddenly, presumably from a cardiac infarct.

Comment—This is the second case of painful arthritis of the shoulder associated with coronary sclerosis that I have treated. In both instances there was a satisfactory alleviation of pain although in neither case was there any change in the radiographic appearance following x-radiation.

This holds true in all of our cases of painful arthritis, particularly hypertrophic arthritis. Inasmuch as we were inter-

ested primarily in alleviation of pain we did not investigate sufficiently to determine the complete clinical effect on the arthritic process itself

Case V Pa f l M fastase

History—F W woman fifty two years of age came complaining of pain which had been present in the right hip and the upper lumbar region for the past several months. The pain has become increasingly severe until the patient is unable to walk. Twelve years previously she had the left breast removed for carcinoma. Nine months later multiple skin and lymphatic metastases developed over the anterior chest. Following intensive radiation the local lesions cleared up. The patient was in good condition for four months when she complained of severe radiating pain down the right leg. Radiography showed a questionable metastatic lesion in the body of the second lumbar vertebra. Three weeks later the pain had completely disappeared and the patient was well until the present illness.

Examination—The pain this time is very severe and radiographic study showed definite metastases in the upper lumbar vertebra with probable involvement of the lower thoracic vertebrae. There were eleven metastatic areas in the neck and characteristic recession of the right femur and the right iliac acetabulum.

Plan of Treatment—X rays were applied through two paravertebral 16 by 8 cm ports over the lower dorsal and upper lumbar region and a dose of 200 roentgen unit (a r) at each port once every day until 1000 units had been given. Transcutaneous ports each 15 by 15 cm over the anterior and posterolateral regions of the right hip were planned to receive 400 roentgen units every third day at a skin temperature of 40°C for a total of 100 units each at the other factors being 00 kVp 70 m target distance filter of 1.5 mm of copper plus 1 mm of aluminum. The patient completed the series in fifteen days at which time pain in the right hip had disappeared and the pain in the lumbar spine had diminished. She was then hospitalized for the last report of the therapy.

Five months later the previous condition has been relieved except for one case on the left of pain over the sacrum. She has been able to walk a few hundred feet.

Radiographic examination has shown no evidence of the destructive metastatic disease.

Comment—This shows the value of x radiation in a somewhat sensitive carcinoma simplex of the breast. Although of course the eventual outlook is hopeless, much can be done to make the patient comfortable. Even though the tumor is not radiosensitive, x radiation should not be withheld for this reason alone. When we are dealing with a malignancy which is prone to metastasize to bone, x radiation is not withheld when pain is present and the radiographic study is negative, particularly if the patient has not suffered pain in the same area prior to the occurrence of the primary lesion. Suffering can be spared the patient if this rule is followed. At times an entirely negative radiographic study may be obtained even in the presence of extensive metastases. In all doubtful cases phosphatase studies are indicated.

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Ex n nst o i—The pan ths t r as ery seve a d dio- o phic st d sho ed lefin te metastases in th pper lumbr r r t rae v th prob ble m ol ment of the lo ve t o dorsal er r brae The e e e tensive mer stat c area in the neck and trochanteric eo n of the r ht f m r a d the r ht lum ab t the cet bulum

Plan of Treatt nt—X ray e appl ed thr h t o p ra r t r ebral 16 by 8 cm p rtals o r the lo r d rsal and uppe lumbar regi n n dosages f 00 entge units (ir) at each p rtal e ery day nt l 1000 nt had b en gi n T o d d t on l p rtals each 15 by 15 cm ov the ante or nd p terolateral regions f the r i ht hip ere planned r r ce 400 roent en u ts e ery th d d v to a s le hip p rtal f total f 1 00 n ts t each a ea the ther f ct rs be 200 kVP 70 cm tar g t d i tan e filt d thr u o h 1 mm f copp r pl 1 mm f aluminu The p t nt c mpl ted th series in fifteen d s at h h time pa i the r ght h p h d dis ppar d d th p i n the luml at sp h d d m h d She s m h t nau tel f r n o th l t t p ct of th th f v e r e

Fi e n ths l t e th p t nt eed noly l l e cept f r an cca ion l t v n o f p o r the sacrum Sh has been abl to l e a fa tly n rn l l e

Rad ogr phic e a n r sh d filling f the destruct e metastatic ar as

SCALENUS ANTICUS SYNDROME

K G HANSSON M D †

WE must all recognize the clinical entity that consists of the following symptoms (1) *pain on the side of the neck* radiating over the scapula in the back and under the clavicle in front down over shoulder upper extremity and into the hand along the course of radial ulnar or median nerves (?)

vascular symptoms of diminished pulse or blood pressure on the affected side (3) *vasomotor complaints* of ischemia or temperature changes and (4) *tenderness on pressure* over the scalenus anticus muscle or brachial plexus When a patient presents these symptoms we think of a possible cervical rib spasticity of scalenus anticus muscle brachial plexus neuritis or radiculitis due to cervical arthritis After arthritis and focal infections have been ruled out we still have a group of cases in which the symptoms are undoubtedly due to mechanical pressure

PATHOLOGY

When we review the skeletal structures in this region we find the vertebral column the main support against gravity The weight that this column has to support is represented by the scapula and the upper extremity This weight is suspended on the vertebral column by means of muscles such as trapezius levator scapulae and rhomboids The sternoclavicular joint is the fulcrum for the motion of the scapula The position of the scapula and the arm in relation to the vertebral column determines the relation between the superior outlet of the thorax and such structures as the subclavian artery and vein and the brachial plexus The thoracic superior outlet is

F m th	D p rtm	f Ph	l Th rapy	Corn ll U	rs ty M d
l Coll g	d th N	Y k H p l			
† A	P f so	f C l m e a l	S g ry	(O th p d cs)	Corn ll U
rs ty M d	l Coll g	D ct	f Ph s	l Th rap	N Y k Hosp
l d H p	l f Sp	l S g			

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K G HANSSON MD†

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Γ m h D p m f Pl y l Th py C ll U ty M d
 l C ll g d th N w Y l H pt l
 † Ass P f sso f Cl cal S g ry (Orth ped) Corn ll U
 rs ty M d l Coll g D f Ph l Th raps N Y l Hosp
 l d Hosp l f Sp l S g

congenital recessive atavisms which arise at unstable areas of the spine as in the cervicodorsal and lumbodorsal areas. He describes four types of cervical ribs which usually come off the seventh cervical vertebra. The first type is only an increase of costal process. The second type presents a rudimentary rib extending beyond the transverse process usually with a free end. The third type is a well developed rib which extends to the costal cartilage of the first rib and is often united to it by a ligament. In the fourth type a fully developed rib actually articulates with the first costal cartilage or sternum. Any of these types may be unilateral or bilateral. These structures lengthen the thorax by one rib.

The incidence of cervical rib in the general population is about 0.5 per cent. Any of the four types of cervical rib may produce symptoms due to direct pressure producing stretching, compression or friction against the vital structures passing through the scaleni triangle. Although cervical ribs are usually bilateral the symptoms are mostly unilateral. Only about 5 to 10 per cent of individuals with cervical ribs will develop symptoms. Although distribution of cervical ribs is about equal in both sexes the symptoms are three times more common in women.

3 *Scalenus Anticus Syndrome*—This is often described as an entity but the writer believes it is only rational to assume with Naffziger that injury, excessive occupational strain or poor musculature may cause the shoulders to droop and precipitates the signs and symptoms of the cervicobrachial syndrome. The lower roots of the brachial plexus and the subclavian artery arch upward over the rib cage and over the edge of the scalenus anticus muscle which holds them back or in a more posterior position. The presence of a cervical rib may push the scalenus posticus and medius forward thereby constricting the space between the scaleni muscles through which the subclavian vessels and brachial plexus must pass.

4 *Increased Traction from Within Thoracic Cage*—It seems conceivable that traction of structures going over the upper rim of the thoracic cage from the attached organs within the thorax may produce the symptoms under discussion. In a pneumothorax there may be enough pull from

completely surrounded by rigid bony structures. Posteriorly we have the cervicothoracic spine laterally the first rib and anteriorly the sternum. The lower fibers of the brachial plexus, the sympathetic nerve supply to the arm and the subclavian artery and vein must pass over this rigid outlet and form the apex of an arch as they pass over the first rib. Thus the first rib may be compared to a pulley over which the subclavian vessels and the nerve fibers are stretched. Various

RELATION OF CERVICAL RIB TO SCALENE MUSCLES, NERVES AND BLOOD VESSELS

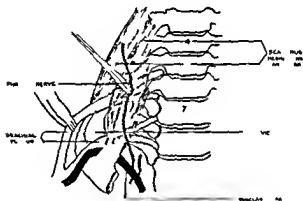


Fig 15

conditions may be visualized which will increase the tension and pressure of these soft structures over the rigid bone.

1 *High First Ribs*—In many cases of cervicobrachial syndrome in which the x-rays rule out cervical ribs, there are no symptoms over the scalenus anterior muscles. However, there is evidence of pressure and the first rib is often found to be placed higher up than usual. The rib is flat with a transverse ridge in the middle of the scalenus tubercle.

2 *Cervical Ribs*—Dr. Patterson has given a detailed description of the anatomy of cervical ribs and describes them as

diagnosis is not difficult although cervical arthritis with radiculitis and brachial plexus neuritis should be ruled out. The patient is usually between the ages of twenty and twenty-five years. I have seen several cases in adolescent girls with high dorsal curvatures but these are easily recognized. The patient usually complains of pain about the shoulder, upper extremity and hand numbness, paresthesia or ischemia may be present. There may be a definite change in the circulation on the affected side—a diminished pulse and a lowered blood pressure. These symptoms are increased on traction of the arm, hyperextension of the neck with the chin turned to affected side. Relief of symptoms is obtained by abduction of the arm—a fact which the patient has usually discovered herself. In advanced cases there may be swelling of the hand and forearm and even ulcers with gangrene have been encountered. Muscular atrophy is also common and the area most affected seems to be the thenar eminence.

TREATMENT

This commentary is offered as an attempt to put the conservative treatment of the cervicobrachial syndrome on a scientific basis. After reviewing the histories of a great many patients who have been referred with various diagnoses but with the same symptoms, little by little a new conception of these pathologic processes described as the cervicobrachial syndrome has developed. This new conception has been analyzed both anatomically and physiologically and has been proved clinically by a definitely outlined treatment.

1. Rest and Support

In acute cases patient should be put to bed with arm suspended over the head to relieve the circulatory symptoms and nerve irritation. If the occupation is suspected as a contributory cause the patient should stop such activity. A sling is essential to take the weight off the extremity.

In cases of descended scapulae, round shoulders, a figure 8 bandage will take the strain off the nerves and blood vessels. The best figure 8 bandage is made by a stockinette through

inside to exert pressure and stretch the blood vessels and nerves over the pulley that is the apex of the thoracic cage.

5 Increased Traction by Scapuli or Upper Extremity in Poor Posture—The cervical spine seems unusually long and the scapulae are low and tilted down and outward. The angle formed by the junction of a vertical line drawn along the posterior spinal processes with a transverse line drawn from the posterior process of the seventh cervical vertebrae to the acromioclavicular joint is less than 90 degrees in the average person. In persons with poor posture this angle measures more than 90 degrees thus representing the pull from outside the thoracic cage against the thoracic rim.

The child is born with a relatively high position of the scapulae opposite the third or fourth cervical vertebra similar to the anthropoid ape. A gradual descent takes place until puberty when the adult position is reached. In the female this descent is greater which may account for the greater incidence of the symptoms of pressure in this sex, the ratio being 3 to 1. It may also explain the rarity of the symptoms of adolescence.

We have therefore a highly placed rim or pulley with increased traction from inside or outside of the thorax. Some of these conditions are congenital but do not appear until the third or fourth decade of life. Some observers have emphasized occupational stress but the etiology is more probably due to a congenital predisposition with the loss of muscular tonus as an excitatory factor.

DIAGNOSIS

After reviewing thirty-two articles on cervical ribs and scalenus anticus syndrome one gets the impression that they are two entirely different entities and that the only treatment is the removal of the cervical rib or resection of the scalenus anticus muscle. Further inquiry among orthopedic surgeons reveals that only 15 to 20 per cent of the patients with these conditions receive operative treatment. Little is written on the treatment of the other 85 per cent. It therefore seems rational to analyze more closely the nonoperative cases which are usually referred for physical therapy. The

The patient clasps his hands together forming the fixed point and in this position first elevates then adducts the scapulae. This is carried out for ten minutes three times a day to increase the tone and thereby the carrying power of the muscles that help support the shoulder girdle (Fig 153 1 ?)

TREATMENT

EXERCISES FOR RHOMBOIDS
TRAPEZIUS AND LEVATOR SCAPULAE



1



3



2



F 153



4

General Postural Exercises—Most patients with the cervicobrachial syndrome have poor body mechanics. The sloping shoulders go with increased dorsal kyphosis which is accompanied by an increased lordosis and tilted pelvis. Therefore general postural correction should go hand in hand with application of the local treatment. The only difference from the usual correction of body mechanics is in connection with the head and neck. If the head is held high and the chin is pulled in, we may exert traction on the scalenus muscle and thereby cause the thoracic pain. The head correction is best omitted or at least modified.

3 Heat

Heat in the form of infra red rays, short wave or diathermy directed to the offending areas, relieves irritation of the brachial plexus and spasm of the scalenus anticus muscles.

which a flannel bandage has been passed and held together by two safety pins.

An *aeroplane splint* is ideal for support and elevation of the shoulder girdle. When an aeroplane splint is not available an inexpensive substitute may be made of *specialist plaster* molded over the crest of the ilium up the flank and high in the axilla, holding the humerus at about a 30-degree angle of abduction, the elbow in flexion. Forearm and hand plaster is held in place with straps and a ring of Mexican felt around the opposite shoulder and can be worn under the clothes inconspicuously.

2 Exercises

(a) **EXERCISES OF POSITION**—Exercises of position consist of maintaining the shoulders high and the arms over the head. This pose will relieve pressure over the bony hum or the scalenus anticus muscle. The head is carried slightly forward to release the scalenus anticus muscle. The neckfirm position is also useful: the upward reach and the hanging of the hands on an overhead bar.

Severe circulatory involvement accompanied by edema is alleviated by *isometric exercises* similar to those used in endoarteritis of the lower extremities. The extremity is elevated until the finger tips become white then lowered in a hanging position till the fingers become dark red. After these two positions the arm is rested horizontally for 15 minutes, and the procedure is repeated for half an hour.

(b) **ACTIVE EXERCISES**—These exercises are of two types: local exercises for the shoulder girdle and general postural exercises.

Local Exercises—The shoulder girdle is hinged in the sternoclavicular joint and can move up and down as well as forward and backward. The weight of the shoulder girdle and the attached upper extremity is counteracted by the pull of the trapezius, the levator scapula and possibly the upper rhomboid muscles. In ordinary life the shoulder girdle acts as a more or less fixed point and the upper extremity with the hand is an active movable point. The treatment of patients with the cervicobrachial syndrome reverses this order

- C g W M d k pp P A Cerv 1 R^t d Sc l A
 Sv d m A S g 105 556 (Ap l) 1937
- 3 Bl D M D F nd M k k W Et l gy f V s l
 Symp m f Cerv al Rb B J S rg 87 406 (J) 1935
- 4 L d k e G C d H m T L Cerv 1 Rb-A o d A urv
 f S b l Art ry A l S g 34 310 (F b) 1937
- 5 T lf d E D 1 S pf d J S V l C mpl f C rv l
 Rub Br J S rg 18 557 (Ap l) 1931
- 6 Bl l gt W T f S b l A urv m A t d h
 C 1 Rb B J S g 19 334 (O c) 1931
- 7 Sm h B C Th mb f Th d P rt f S b l Art v A
 d l S l An Sv d m A S g 111 546
 (Ap l) 1940
- 8 P rt rs R H C 1 Rb d h S l V l S d m
 Ann S g 11 531 (April) 1940
- 9 M f Wm F C rv 1 Rb C g P rt d O l d A
 ry m f S b l A ry A S g 111 549 (Ap l) 1940
- 10 Fl E R A U l V l C mpl f C 1 Rb B t
 J S g 4 6 (J) 1937
- 11 Ad A W d C ff J R C rv 1 Rb A M h d f A
 App h f R l f f Symp m by D f S l A u
 A S g 85 839 (J) 197
- 1 D ld J M d M rt B F Th S l A cu Synd m
 W h d W l Cerv 1 Rb A S g 111 09 (M) 1940
- 1 Ay w rth k H Th C rv B h l Sv d m A S g 111
 7 4 (M) 1940
- 14 G g M S l A Sv d A D g i C firm
 t ry T S g ry 5 599 (Ap l) 1939
- 15 N ff g H C d G W T N f B h l Pl vu
 M h l O g h S l Sv d m S g Gy &
 Ob t 67 72 (D) 1938
- 1 S pf d J S B d T lf d E D C mp ss f L w Tru k
 f B h l Pl vu by f D rs 1 Rb B J S g 7 168 1919
- 17 O h A G g M d D t k y M S l A (N ff
 g) Sv d m Am J S g 8 669 (J) 1935
- 18 Sp L g R G d B df d F k S l V l rv C
 p A S g 107 08 (M y) 1938
- 19 F b g J A Th S l A V l R l t Sh ld
 d A m P J B & J S g 20 860 (O) 1938
- 0 P h E W A m f C 1 Rb W h R p f C B
 J S g 16 35 (O) 1938
- 1 k m L P d B Wm C 1 Rb A J S g 30
 7 (N) 1935
- H ll R M V l A m l f Upp Lmb A t d W l
 C rv 1 R^t R p f C d R f L tu I t J
 S g 105 (J h) 1939
- 3 E I C V l Compl ns f Cerv 1 Rb d First Th
 Rb Ab m l B J S p 7 111 (J ly) 1939
- 4 Kl b g S d L M A H d h A Sv p m f C l
 Rb A S g 105 99 (F b) 1937

4. Surgical Treatment

We owe most of our present knowledge of the cervicobrachial syndrome to the surgeons. With the advent of the x-ray numerous articles on the cervical rib appeared. By 1911 Keen had operated in forty-three cases. Adson and Coffey in 1917 first recommended section of the attachment of the scalenus anticus muscle to relieve pressure. Litterson and Donald speak of cases in which both cervical rib resection and scalenectomy are indicated. However the number of patients operated on is a small percentage of all who present themselves with cervicobrachial symptoms.

CONCLUSION

1. Cervical ribs, a spastic scalenus anticus muscle or poor posture may produce identical symptoms.

2. The common etiology in all cases is probably a lowering of the tonus in the muscles supporting the scapular weight. The irritation, traction and pressure on the cervical nerves and subclavian vessels by the first rib, a cervical rib or a spastic scalenus anticus muscle in all probability will explain the cervicobrachial syndrome.

3. This syndrome includes pain along the brachial nerves, vascular changes of pulse and blood pressure, vasomotor symptoms of pallor, cyanosis and changes in temperature and in addition tenderness over the scalenus anticus muscle and brachial plexus.

The conservative treatment of rest and support, heat to relieve pain and spasm, massage to increase muscular tone and exercises to build up muscular support are essential. Postural correction of body mechanics is important. Although surgical interference is necessary in a small percentage of cases in which circulatory failure in the arm may mean an emergency operation, the majority of the cases respond to conservative treatment as outlined here. Even in operative cases the procedure outlined here is of complementary importance.

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PRIMARY AND SECONDARY (RENAL) HYPERPARATHYROIDISM

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It is the clinicopathologic effects of parathyroid hyperfunctioning that represent what we shall mean by hyperparathyroidism. Recent advances have shown more and more clearly that cases of hyperparathyroidism fall into two categories: primary (or idiopathic) and secondary.

The *primary* cases are those in which the point of origin of the disease is apparently in the parathyroid glands themselves, since there is no known explanation of what instigates their hyperfunctioning. The parathyroid abnormality in cases of primary hyperparathyroidism may be of the nature of a tumorous growth (an adenoma) usually limited to a single gland, or it may be of the nature of a hyperplasia affecting all (i.e. the theoretical four) parathyroids. In cases of *secondary* hyperparathyroidism the point of origin of the disease is elsewhere than in the parathyroid glands themselves. Actually it seems to be exclusively in connection with renal insufficiency of long standing that one may observe a pronounced secondary hyperplasia of all the parathyroids resulting in a complicating or secondary clinical hyperparathyroidism. Thus the division into primary and secondary hyperparathyroidism is made on the basis of absence or presence respectively of some plausible instigating factor for the parathyroid hyperfunctioning.

As a clinicopathologic complex, hyperparathyroidism in its full efflorescence has three central facets—parathyroid, renal and skeletal alterations. This is true whether the case being dealt with is one of primary or one of secondary hyperparathyroidism. Thus in a case starting out as an instance of primary hyperparathyroidism the kidneys may become so

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- 6 Th. F. V. Sc. 1. A. cu. S. 1. d. Cerv. 1 Rb. S. rger. 6 11 (J. 1) 1939
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- 3 Br. k. Wal. W. Br. h. 1 Pl. vu. P. essu. b. th. N. rmal. Frst. Rb. Ann. S. rg. 11 857 (J.) 19 7

suspected until the dramatic fact of a *pathologic fracture* leads to the diagnosis. The way to the latter is also sometimes first opened up through the discovery of a bone swelling from a so called brown tumor—most often in a jaw bone. Furthermore there are many cases in which *renal symptoms* and notably those of renal calculus are the presenting ones and the skeletal alterations are in the background or even equivocal. Occasionally *gastro intestinal symptoms* such as attacks of abdominal pain, nausea and vomiting are prominent and even the presenting phenomena and if the skeletal alterations are not clinically obvious may confuse the surgeon as to the true nature of the condition.

Unless the offending parathyroid tissue is removed the disease usually progresses. On account of porotification rendering the skeleton susceptible to repeated fractures and deformities the patient is likely to become hopelessly bedridden. The gravity of the condition is usually increased by the presence of renal insufficiency associated with the presence of renal calculi and pyelonephritis and even renal calcinosis. There is wide variation in the speed with which such a course is run. When the condition has reached this stage even removal of the offending parathyroid tissue may no longer save the patient's life since the renal changes are by now often irrevocable. Fortunately primary hyperparathyroidism is now usually properly diagnosed before it has advanced far enough really to devastate the skeleton (Figs. 154-155) and irreparably damage the kidneys.

Differential Signs of Chemical Findings

Hypercalcemia—Hypercalcemia (that is a serum calcium value above 11.5 mEq per 100 cc.) is a crucially important diagnostic criterion of hyperparathyroidism especially if such a value is obtained in several successive assays. In this connection it should be noted that in normal adult the serum calcium is usually between 9.5 and 10.5 ± 0.5 mEq per 100 cc. by the standard method of assay now employed. The narrowness of the range of normal variation and the pitfalls of the test technique make it imperative that there be no doubt as to the accuracy with which the test is performed. This is true especially if unequivocal bone changes are absent and one is therefore compelled to rely

severely damaged that the consequent renal insufficiency in turn increases the parathyroid hyperfunctioning and thus exacerbates the whole state of hyperparathyroidism. On the other hand in a case starting out as an instance of hyperparathyroidism secondary to renal disease the parathyroid hyperfunctioning which may develop may become so pronounced that it in turn also acts powerfully upon the bones and even again upon the kidneys.

For the surgeon the problems of hyperparathyroidism are mainly those of diagnosis (including differential diagnosis) and treatment. However the distinction between primary and secondary hyperparathyroidism may be difficult to make even when the presence of hyperparathyroidism is clear. Indeed in an occasional instance it may not be possible to tell definitely from the total clinical complex presented or from the biochemical findings in the blood whether the hyperparathyroidism is primary or secondary. This fact has important bearings upon the questions of treatment and prognosis.

DIAGNOSIS OF PRIMARY HYPERPARATHYROIDISM

Incidence Primary hyperparathyroidism while not a common disease is not rare. Its incidence seems to be at least two or three times as high among females as among males. It occurs most frequently between the ages of thirty and sixty years. While it is not uncommon at other ages also (notably between twenty and thirty years) it seems to be definitely rare below ten years. No racial, hereditary, dietary, or environmental factors in the incidence of the disease have been definitely established.

Cons of the Dis-e

The onset of the disease is usually insidious and its course protracted. The subjects are likely to complain early of *ague* *aching pains* especially in the limbs and of *stiffness* in joints. The clinical manifestations may be misinterpreted for months or years. Indeed the presence of the disease sometimes not

Th pp d d b bl traphy sel et d p l d ppl m
d h bj h l

suspected until the dramatic fact of a *pathologic fracture* leads to the diagnosis. The way to the latter is also sometimes first opened up through the discovery of a bone swelling from a so called brown tumor—most often in a jaw bone. Furthermore there are many cases in which *renal symptoms* and notably those of renal calculus are the presenting ones and the skeletal alterations are in the background or even equivocal. Occasionally *gastro intestinal symptoms* such as attacks of abdominal pain, nausea and vomiting are prominent and even the presenting phenomena and if the skeletal alterations are not clinically obvious may confuse the surgeon as to the true nature of the condition.

Unless the offending parathyroid tissue is removed the disease usually progresses. On account of porotification rendering the skeleton susceptible to repeated fractures and deformities the patient is likely to become hopelessly bedridden. The gravity of the condition is usually increased by the presence of renal insufficiency associated with the presence of renal calculi and pyelonephritis and even renal calcinosis. There is wide variation in the speed with which such a course is run. When the condition has reached this stage even removal of the offending parathyroid tissue may no longer save the patient's life since the renal changes are by now often irrevocable. Fortunately primary hyperparathyroidism is now usually properly diagnosed before it has advanced far enough really to devastate the skeleton (Figs 154-155) and irreparably damage the kidneys.

D g t S g f e f Ch m l F d g

Hypercalcemia—Hypercalcemia (that is a serum calcium value above 11.5 mg per 100 cc) is a crucially important diagnostic criterion of hyperparathyroidism especially if such a value is obtained on several successive occasions. In this connection it should be noted that in normal adults the serum calcium is usually between 9.5 and 10.5 ± 0.5 mg per 100 cc by the standard methods of analysis employed. The narrowness of the range of normal variation and the pitfalls of the test technique make it imperative that there be no doubt as to the accuracy with which the test was performed. This is true especially of unequivocal bone changes as evidence and one is therefore compelled to rely

Fig 154



Fig 155

Fig 154—Cad f th rx two- -old m re cal g d ast
 f h k l h h perp rathv dism D h occur d
 19 5 wh h p ts ra m l rs d f h
 d sease rd th pre n f so h se k l l m l m
 F 155—Th l g bo d from th l lumb t p
 sh n bo emph zi g h x em curv d irregular d st
 ti

very heavily upon the serum calcium value in connection with the diagnosis.

However while the presence of a hypercalcemia is strong evidence in favor of a diagnosis of primary hyperparathyroidism hypercalcemia is not infrequently found also in cases of multiple myeloma and though rarely in cases of carcinoma extensively metastatic to the skeleton (See Differential Diagnosis).

On the other hand in cases of primary hyperparathyroidism in which chronic renal insufficiency has resulted from the presence of bilateral renal calculi and pyelonephritis with or without bilateral renal calcinosis there may be only an equivocal hypercalcemia or the calcium level may even be normal. This fact is to be related to retention in the blood of products which are not being excreted by the damaged kidneys and particularly to the rise of the serum phosphorus level considerably above the normal. It is well known that a rise of the serum phosphorus level is associated with a reciprocal depression of the serum calcium level. Cases of hyperparathyroidism presenting high serum phosphorus and equivocal or normal serum calcium levels often give one the serious problem of deciding whether the hyperparathyroidism is primary or is merely secondary to renal disease. For further details on this question see the discussion of secondary (renal) hyperparathyroidism.

Hypophosphatemia.—For purposes of comparison one should know that in normal adults the serum inorganic phosphate is usually between 2.5 and 3.5 mg per 100 cc as determined by the methods generally used. Hypophosphatemia (that is a serum inorganic phosphate level below normal) like hypercalcemia is very helpful in the diagnosis of primary hyperparathyroidism. Indeed a combination of a hypophosphatemia with a hypercalcemia is exceedingly strong evidence in favor of the diagnosis. Nevertheless in cases in which there is already slight renal insufficiency the serum inorganic phosphate level is very likely to be below normal while the serum calcium level may still be above normal. Even if the phosphate level is not yet high enough to have depressed it very far. Furthermore it should also be noted that a hypophosphatemia may be observed in cases of adolescent rickets and osteomalacia. In such cases the serum calcium level will be normal or tend to be subnormal.

Serum Phosphate Activity.—In cases of primary hyperparathyroidism in which definite bone changes have developed the serum phosphate activity is regularly increased in accordance

with the severity of the bone lesions, the degree of this activity ranges between 8 and 40 Bodansky units (i.e. roughly between two and ten times the maximum normal amount). When the bone changes are only incipient or as yet not apparent the serum phosphatase activity is within normal limits or only very slightly elevated. It should be noted also that in cases of hyperparathyroidism secondary to renal disease the serum phosphatase activity will likewise be strikingly increased if skeletal alterations are prominent. Furthermore an increased serum phosphatase activity is to be found in connection with other conditions also and notably in Pictet's disease, osteoplastic metastatic carcinoma and steogenic sarcoma.

Calcium and Phosphorus Balance Studies—It is true that when placed for a three day period on a diet low in calcium (and also standardized as to its other ingredients and its acid base equivalents) a patient with clear cut hyperparathyroidism has a much greater loss of calcium, and usually also of phosphorus by way of the urine and feces than a normal subject. However to make a calcium phosphorus balance study of value requires so much attention to numerous details that for practical clinical purposes it is not worth while in connection with making a diagnosis. Furthermore it should be noted that in mild case of hyperparathyroidism the new bone calcitonin and phosphorus balance found (even in a period of low calcium intake) is sometimes not sufficiently pronounced to have diagnostic significance. Finally it is a fact that hyperparathyroidism is not the only condition in which strongly negative calcium and phosphorus balances are likely to be found. For instance they have been noted also in osteomalacia, hyperthyroidism, chronic tetraetheria and malnutrition especially metastatic to the skeleton.

Röntgenography Diagnosis

The skeletal alterations observed by roentgenographically vary widely in accordance with the stage of evolution of the disease. When the skeletal changes are mild one may find merely that the cortices of the bones are *rarefied* even without being thinned and that their spongiosa appears somewhat obscured. In other cases one may note also the presence of slight *subperiosteal scalloping* of the cortices of some of the long bones. In such cases the diagnosis of hyperparathyroidism must rest on the evidence until it is well confirmed by the clinical and laboratory findings.

Indeed an unequivocal roentgenographic diagnosis of hyperparathyroidism can safely be made only when the lesions

Fig 156



Fig 157

Fig 156-R g g m f h m ru p g p l l g fra
 h gl fi d y f h p rp ra h dism
 m g d f rrv rs It eru th c d g t h h st ry h
 l d h d som lgh p b h k d h p d th l was b
 g l t f kyph l H w c h p h
 l g f h l d h d gnos A gl b l p ra hy d d m
 n g 3 cm d m d gl g 13 gm p d Th
 f h h l d d l fi f h k l p d d p dl
 Fig 157-R g g m f part f p l d pp p rt ns f
 f m ra f m h all ra d Fig 156 h p f th b
 d h l Ik f h d w h l l f h d m

in the bones are fairly advanced. In such cases the cortices of the bones are *thinned* and the spongy bone ends show *blur*

ring of the trabecular outlines. Also the circumference of some bones may be expanded in places by the presence of cysts and brown tumors. In addition there may be infections and fractures. Indeed as noted it may be a bone swelling or a pathologic fracture that first leads to the discovery that hyperparathyroidism is present (Figs 156-157-158).



Fig. 158



Fig. 159

Fig 158—Roe g era t h d th f m h m th
 l on f hyp ip rathy d sm fir pect d b d st
 f a l cal l ll g f a l d pp l s e ll d
 g e ll m Th b f h ar kl r m h
 ra fi d s d m v b s ll g v pes l l ll ra th
 f r f h pl l e d d h b f h fl h m
 pl bo l arl p d d l h f h r v d h perplax
 p hy d f d
 Fig 159—R e g m f l m fr c ll d l g
 (158 h p l gra l m t l g Thus p mad l b re
 k l l f h f h l d p hy d d ll l
 u fraon f l f nh m d Th h l l
 h m l g f hyperp h d sm d r h h l
 ff y (Th th dcb d t D R b Oct b g f h
 ve f hese p tu)

In the rare cases in which the disease is found well developed in older children or adolescents the bone changes visible roentgenographically may suggest those of adolescent rickets. In such cases the long tubular bones in particular may show bowing, widening of the metaphyses and slipping of certain epiphyses. In advanced cases of hyperparathyroidism a peculiar granular mottling of the calvaria is very likely to

Fig 160



Fig 161

Fig 160—Pl m g ph ($\times 6$) f h mpl ly ra f rm d
 l ri m h g h pp p t f h p t l g fib u
 h h h g ss pp d b h d h h p c li d
 g c li tum b w tum l su h p h l g h ges th
 p d h p ru f gra l m cl g f th l m
 Fig 161—R g g ph f b f mddl g d m k t
 l b ff g f m al l l f l h p fi years d
 h h d d rg p rat f h d Th h was l
 ff ri g f m hyp rp ra hy d m disc d ally f
 fl h l l h d h r h b k Wh l tt w g g pl d
 was f d h h w y t h l f l m th pp d f
 h gh f m d h b h wn h ll H rum
 l m l 14.2 mg serum ph ph ru 19 mg d rum ph
 ph 65 B d nsky A p ra hyro d d m f b t h f
 pl m w m d d hu p ratu y u b l
 h d g d bl p

be found. The mottling represents the shadow cast by new bone and connective tissue that has replaced the original bone (Figs 159-160).

Sometimes the bone changes of hyperparathyroidism have first been discovered during x-ray examination of the kidneys for stones (Fig. 161). In fact the presence of this disease should always be suspected in any case of even mild osteoporosis, if the latter is associated with renal calculi. Furthermore it should be noted that in a case of hyperparathyroidism which has developed secondarily to primary renal disease and chronic renal insufficiency the skeletal changes to be found roentgenographically may be indistinguishable from those seen in cases of primary hyperparathyroidism. Indeed in a child or adolescent suffering from hyperparathyroidism the great likelihood is that this has developed on the basis of primary renal disease. These cases fall into the category of so-called renal rickets with a secondary or complicating hyperparathyroidism.

DIAGNOSIS OF SECONDARY (RENAL) HYPERPARATHYROIDISM

The reader will have noted that in the discussion of the diagnosis of primary hyperparathyroidism reference has always been made to the relevant findings in secondary (renal) hyperparathyroidism. Renal hyperparathyroidism develops of course on the foundation of renal disease and specifically a protracted renal insufficiency. The latter leads to pronounced hyperplasia and hyperfunctioning of all four parathyroid glands which ultimately induces in its turn severe skeletal changes essentially similar to those seen in primary hyperparathyroidism. Thus both in childhood and in adult life hyperparathyroidism may be present as a complicating or secondary disorder even if renal disease is the underlying one.

In childhood or adolescence the protracted renal insufficiency usually develops on the basis of a congenital defect (structural or functional) of the kidneys or urinary tract. This defect may be a congenital defect of renal development such as polycystic kidneys. On the other hand the kidney damage may follow some sort of a functional difficulty at the

urethrovessical sphincter which from early life has interfered with the outflow of urine. Sometimes the presence of a congenital defect cannot be established and the renal insufficiency seems to be attributable to a primary pyelonephritis or a glomerulonephritis of long standing.

As a rule in these cases of secondary hyperparathyroidism of childhood or adolescence the bones are *stunted* present *rachitoid deformities* at the sites of endochondral bone growth and also show general *porosis* and *fibrosis*. The calvarium may present granular mottling. Clinically these young subjects are not only deformed but undersized and sometimes also manifest infantilism and altogether such cases have been described under the heading of renal rickets. Terminally in these cases *calcareous deposits* (metastatic calcifications) are sometimes found in various soft tissues. They are likely to be most prominent in the media of moderate and larger sized arteries in the soft tissues near joints and in the subcutaneous tissues and skin in general.

In adults secondary hyperparathyroidism from protracted renal insufficiency is very rare. In these cases the underlying renal disease may be a glomerulonephritis which for some unexplained reason is running an exceptionally protracted course. On the other hand it may be bilateral renal calculi and pyelonephritis or even congenital polycystic kidneys. In these cases which in general represent the adult equivalent of renal rickets of childhood while stunting and rachitoid deformities are of course absent the bones present essentially the same other changes as those appearing in the cases developing earlier in life. Terminally in these cases too metastatic calcifications may appear.

As for the *blood chemical findings* there is an elevation of the serum inorganic phosphate value (which may reach levels of 10 mg. or more per 100 cc.) and some depression of the serum calcium level is not infrequently observed. On the other hand it is not uncommon for the serum calcium to be somewhat above normal although the serum phosphate is increased. The serum phosphatase activity also rises. Taken as a whole these findings are diagnostically important only when it can be established that it was renal disease that precipitated

the entire disorder for indeed they are similar to the findings in cases of primary hyperparathyroidism in which a complicating chronic renal insufficiency from renal calculi and pyelonephritis or renal calcinosis has developed.

In a child or an adolescent the presence of unexplained stunting, unexplained acidosis (nonacetone) or unexplained renal disease separately or together should suggest the possibility of secondary (renal) hyperparathyroidism even if no rachitoid lesions are manifest clinically. Furthermore in any case of so called late rickets no matter how genuine it appears one should make certain by searching for renal insufficiency that one is not dealing with renal hyperparathyroidism instead. Certainly if the subject is less than ten years of age the other possibility—that the condition is primary hyperparathyroidism—can almost definitely be ruled out since the latter condition hardly ever appears at such an early age. On the other hand in an adult the differential diagnosis between primary and secondary hyperparathyroidism is sometimes difficult. A history of renal disease (glomerulonephritis or pyelitis and pyelonephritis) in the absence of renal calculi or renal calcinosis weighs heavily in favor of the diagnosis of secondary hyperparathyroidism. Nevertheless an occasional instance of secondary hyperparathyroidism may develop on the basis of bilateral renal calculi and pyelonephritis. Still in a case of hyperparathyroidism in which renal calculi are present one must certainly consider first the idea that the renal aspect of the disease is secondary to primary parathyroid hypertunction.

DIFFERENTIAL DIAGNOSIS

Let it be assumed first that a case under consideration is one in which secondary hyperparathyroidism does not come up as a diagnostic possibility and that the problem is to decide whether one is dealing with primary hyperparathyroidism manifested in Recklinghausen's disease of bone or with some other skeletal disorder. There are a number of diseases involving the skeleton which may present this problem of differential diagnosis. Avoidance of confusion is facilitated by remembering that hyperparathyroidism is after all relatively

uncommon. Because of this fact in a discussion of whether or not a given case is one of hyperparathyroidism the burden of proof lies upon the affirmative side. The conditions whose manifestations sometimes raise this problem of differential diagnosis include adolescent rickets and osteomalacia, idiopathic steatorrhea, senile osteoporosis, cancer extensively metastatic to the skeleton, multiple myeloma, Paget's disease, and fibrous dysplasia of bone.

Adolescent Rickets Osteomalacia Idiopathic Steatorrhea—In the United States adolescent rickets is by no means common at present, and genuine osteomalacia of adults is really rare. Aside from what is revealed by the history, serum calcium determinations aid in the diagnosis. In both adolescent rickets and osteomalacia, as contrasted with hyperparathyroidism, the serum calcium level is at or below the normal. This is also likely to be true in cases of idiopathic steatorrhea, and in these cases the gastrointestinal history also sheds light.

Senile Osteoporosis—Occasionally senile osteoporosis too is mistaken for hyperparathyroidism, but in the former condition the serum calcium, phosphorus, and phosphatase activity values are normal unless there are fractures. In the presence of the latter, the phosphatase activity value may be found elevated, but not of course the serum calcium value.

Carcinosis of the Skeleton—Cancer extensively metastatic to the skeleton sometimes also raises the problem of differential diagnosis. The diagnostic difficulty is most likely to appear if, as happens in rare extreme cases, the metastatic bone involvement is associated with a hypercalcemia. In any event, even if the primary growth is not clinically evident, there is one roentgenographic feature which can prevent the diagnostic error. This is the fact that in cancer, no matter how extensive the rarefaction of certain bones may be, or how strongly their appearance may suggest Recklinghausen's disease, other bones, and sometimes even parts of badly affected bones, will be found relatively normal roentgenographically. In Recklinghausen's disease, on the other hand, when some bones are badly affected, all the rest will be found at least somewhat altered.

Multiple Myeloma—Not infrequently cases of multiple

myeloma are misinterpreted at least temporarily as instances of hyperparathyroidism. It is the relatively common finding of a hypercalcemia in multiple myeloma that is at the bottom of this confusion. However in the presence of this finding further investigation of the blood may reveal a hyperproteinemia with an inversion of the albumin globulin ratio. These two findings should be immediately recognized as the clue to the presence of multiple myeloma. Furthermore multiple myeloma is characterized by the fact that the serum phosphatase activity tends to remain normal no matter how extensive the skeletal involvement may be. In addition, it is well known that a good percentage of cases of multiple myeloma also show sooner or later a Bence Jones proteinuria.

Paget's Disease—In uncomplicated cases of Paget's disease the serum calcium values are normal. Very rarely however a case of Paget's disease is encountered in which routine biochemical study reveals a definite hypercalcemia. These cases must be interpreted as instances of Paget's disease complicated by hyperparathyroidism or at least instances of the coexistence of the two diseases in the same subject.

Fibrous Dysplasia of Bone—This condition is frequently and unnecessarily misdiagnosed as hyperparathyroidism. Clinical reference to the condition has also been made under such names as unilateral fibrous osteodystrophy, unilateral Recklinghausen's disease, disseminated osteitis fibrosa, osteitis fibrosa in multiple foci, and so on. The condition usually manifests itself in childhood or early adult life and evolves slowly pursuing a protracted clinical course characterized by pain, deformity, and a tendency to pathologic fracture of affected bones. Precocious menstruation and hyperpigmentation of the skin may be observed in very severe cases whose clinical manifestations have begun very early in life. It is because roentgenographically the affected bones appear widened, show thinned cortices, and often present appearances suggesting the presence of cysts that these cases are so often misinterpreted as instances of hyperparathyroidism. The fact that the lesions are unilateral or mainly unilateral and that the unaffected bones are normal should be enough to exclude hyperparathyroidism. Furthermore the serum calcium and

phosphorus values in these cases show no deviation from the normal

PARATHYROIDECTOMY

In principle the treatment of *primary hyperparathyroidism* consists of surgical removal of the offending parathyroid tissue. In about eight or nine cases out of ten this will be found to be an adenoma of a single gland (Fig. 167). On the other hand the case may be one of primary hyperparathyroidism resulting from two adenomas or from idiopathic hyperplasia



Fig. 167.—Thyroid gland showing a large adenoma of the parathyroid gland. The adenoma is labeled 'ADENOMA'.

of the four glands. More often than not the surgeon can correct the pathologic state at a single operation, whether the case has developed on the basis of an adenoma of one or two glands or a hyperplasia of all. However, an aberrantly located adenoma not found at the original operation may create the need for a second or even a third intervention, and the patient or a responsible member of his family should be prepared in advance for such a contingency. Such a need may arise also if, in treating a case in which all the glands are

myeloma are misinterpreted at least temporarily as instances of hyperparathyroidism. It is the relatively common finding of a hypercalcemia in multiple myeloma that is at the bottom of this confusion. However in the presence of this finding further investigation of the blood may reveal a hyperproteinemia with an inversion of the albumin globulin ratio. These two findings should be immediately recognized as the clue to the presence of multiple myeloma. Furthermore multiple myeloma is characterized by the fact that the serum phosphatase activity tends to remain normal no matter how extensive the skeletal involvement may be. In addition it is well known that a good percentage of cases of multiple myeloma also show sooner or later a Bence Jones proteinuria.

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improvement of the renal function if that is possible. As to the parathyroids it is questionable whether they should be touched at all in any case of renal hyperparathyroidism (renal dwarfism of childhood or its equivalent in adults). If sufficient parathyroid tissue is removed in such a case the hyperparathyroidism will be interrupted it is true but the end result (death from uremia) may not even be delayed.

Postoperative Complications and Precautions

Hypoparathyroid tetany associated with the development of a hypocalcemia is a common postoperative complication. Often on the day following the operation numbness and tingling—precursors of the tetany—already appear in the fingers and toes. Another postoperative complication which is common is *oliguria*. This usually corrects itself however after a few days. It is to be noted that if at the time of operation advanced renal damage (nephrocalcinosis or pyelonephritis) exists great danger of subsequent death from uremia will remain.

Immediately after parathyroidectomy precautions should be taken to prevent the onset of tetany. Large amounts of soluble calcium salts given by mouth are often effective. Because of the rapidity with which calcium salts are eliminated after ingestion it is also desirable to give them frequently. For instance 4 gm. of calcium lactate may be given every two or three hours during the day and perhaps somewhat less often during the night. When the presence of tetany makes prompt effects urgent the intravenous injection of 10 cc. of *calcium lactate* or *gluconate* may be necessary. If the administration of calcium by mouth does not adequately elevate the serum calcium the desired result can be achieved through the supplementary injection of parathormone. To this end 10 or 20 units of the *parathyroid extract* may be given several times daily for a while (subject to control by determinations of the serum calcium). In addition the diet of patients suffering from latent tetany should be low in phosphorus.

Against tetany one may also use A.T. 10 (*dihydrotachysterol*). The optimal dose varies widely depending upon the severity of symptoms and the degree of hypocalcemia. The

hyperplastic the amount of parathyroid tissue removed has been insufficient and recurrence of the hyperparathyroidism has resulted.

After exploring the parathyroids on both sides of the neck it may be found that those which have been visualized are apparently not at all enlarged. In such a case there must be an adenoma present which is aberrantly located perhaps between the esophagus and trachea but most probably in the superior mediastinum. Of course most of the adenomas are not so located and after the parathyroids are visualized and found to be normal on one side it is usual to find the adenoma on the other side in the general area where another parathyroid would be expected.

If in exploring the neck the surgeon finds all four of the parathyroids very much enlarged there is the delicate decision as to how radical the parathyroidectomy should be. Certainly three of the hyperplastic parathyroids should be removed and it is even safe to remove all but a tiny fragment of the fourth. Several bits from the removed part of the fourth can then be transplanted into pockets made in the sternocleidomastoid muscle and the mouths of these pockets closed with black silk ligatures to mark their position. In this site or in pockets in the abdominal wall the transplants could thus be easily approached should their removal be indicated later on. In any event in these cases the surgeon must recognize on the one hand the danger of recurrence of the hyperparathyroidism from regrowth of the remaining stump and on the other hand of the development of intractable hypoparathyroidism from damage to the essential remaining tissue.

When the operative intervention is successful the pathologic state is abruptly interrupted and soon begins to be reversed. In fact substantial healing of the skeletal lesions may be manifest within a few months even to the point of great reduction in the size of cysts and brown tumors. On the other hand deformities do not become spontaneously corrected to any great extent after they have once developed.

Let it now be assumed that the case is one of *secondary hyperparathyroidism* following upon chronic renal insufficiency. In such a case attention should be concentrated upon

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indiscriminate use of the substance either alone or in combination with other drugs intended to combat the hypocalcemia is fraught with the danger of hypercalcemic intoxication. In using dihydrotachysterol it should also be borne in mind that its effect is cumulative so that its use must be controlled by periodic determinations of the serum calcium value. An initial dose of 5 to 10 cc daily by mouth for three or four days to be followed by a maintenance dose of 2 cc twice or thrice weekly for a time can be expected to control the tetany in most cases. There is no evidence of harmful effect of this maintenance dose even if used over a longer period provided that the dosage is properly controlled by serum calcium determinations.

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CUMULATIVE INDEX

An f l F b 71
 Ab f l g Ap l 44
 f h p Ap l 44 476
 p phn F b 149 155
 Ad d m t h F b 237
 Ad d recu f t em l
 F b 5
 Adhes l post p
 F b 7
 Adh plas ra
 d f tu f fem F b
 105
 A am n p t g
 oom d Ap l 364 366
 372
 Al rnl g d l e t F b
 61
 Al l l j nt asp l f
 l f f p Feb 177
 f ng m l rv F b 171
 gas n ga gl 12
 p ph l d 171
 Amp ns t re l l
 F b 217
 dyl Call i F b
 216 217
 A b pe o mp
 Ap l 445
 A b f Ap l 381
 A lges g ra f Ap l
 601
 A m pl ple t y f
 F b 55
 A h rt f p l d
 g ry F b 181
 loc l f p l d su g ry
 F b 197
 f usll y F b 49
 A kl tub l Ap l 575
 A p d Ap l
 37
 A ty p l i es
 Ap l 548
 Apo ros l p f cu f
 gu l h rn Ap l 597
 App d ce m m l pl tu g
 h F b 1

Art l l n t mp t
 t F b 17
 g cal t tme F b 199
 A t my F b 06 10
 Arthr p f l ra lg
 Ap l 607
 A p f l mpy
 Feb 88
 A th f r p l l
 g ry F b 181
 B ck p bl m d tri l Ap l 515
 B l gy g l Ap l 319
 B t ri ph g h st m
 lu Ap l 588
 phyl l f t Ap l
 40
 B c d Ap l 51
 B d l b ru d
 F b 8
 B c d pl ct m f
 F b 55
 B pp m h d ch my l
 Ap l 589
 Bl d f n S T amf
 B pl t ge F b 83
 98 111
 m l F b 83 98 108 113
 B es tube cul April 565 577
 B k my m d fi d F b
 123
 B k t d f
 f f m F b 106
 B rs f h d f Ap l
 473
 C lla ex n dyl mp
 F b 16 217
 C b l Ap l 399
 C m f sp m d
 Ap l 540
 Ca l D k t tm f h
 m l Ap l 586
 f d Ap l 327 386
 Cell l p oc cal f h d
 Ap l 419

Glossopharyngeal re exposu
Feb 164

n ro my F b 14

Gram duu Ap 1 35

H mf cu n Ap 1 455

spl ts, April 46-464

H al g f w d April 377

H dry s e l u by Ap 1
35

m use, st l au b April 333

H m ly ins, b r l Ap 1 505

H m lyu tr ptoe cu i f t

Ap 1 404 405

H parin us of cu cul

lusa ns, F b 18

H gu l po

l p f e c April 597

dir t p f F b 15

dir t, pa f F b 13

H ru ti f re reb l d k

F b 196 April 524 536

H ru h phy gu l e h

F b 9

H rp z y les Ap 1

605

H p dnl t g l Ap 1

553

tub cul Ap 1 572

H mp F b 264

H yp rpa hy d m prum ry

Ap 1 616

d ry (l) Ap 1 616 630

Hy t my g l h

F b 73

L EO W tz l F b 30

Imm l g l p cts f g l

f ti April 501

l d tr l b k p bl m Ap 1 515

l f ti p ra Ap 1 330

post p rau Ap 1 331

g l April 324

h m h rapy Ap 1 479

m l g l p Ap 1

501

sympos m Ap 1 317

l gu l h po osas

l p f Ap 1 597

d p f F b 15

d p f F b 13

h rn h phy h F b 9

I trum ts, no-t ch t ch c

F b 94

te l t April 345 35

I t tal cu p ly f r p l

m ry tube cul F b 84

I re reb l d h h r f

F b 196 Ap 1 54 536

l n l dl p p t

p n d g l t t

m e F b 27

b ruct F b 19

pe t hn f l i

d d m

F b 6

l ral ast F b

I p n l l l l f

l f f p F b 177

J ce l m l pl m

f F l 54

J tut l Ap 1 56

J gul mp t Ap 1 5

k s F b 7

k rug g Ap 1 50

k k t l b tru d

F b 28

k b l f p l 573

k mm ll d f p Ap 1

539

l cu l F b 179

l t h l

F b 94

Laryng l rv hv

d my F b 33

L g g Ap 1 520

L k d b l Ap 1 505

L h pl m f

F b 56

L mb l m l Ap 1 528

L g b Ap 1 44

tub l Se d T b

l

Lymph g rs f h d Ap 1 469

M coo h rapy h

my l Ap 1 590

M l g g b k ; Ap 1

53 534

Cereb. l. h. l. sy. d. m. m. l. es. April 611
 Ch. l. du. f. et. April 354
 Ch. m. h. pv. p. d. f. f. ru. F. b. 100
 f. su. g. cal. f. et. s. April 49
 f. ds. Ap. l. 39 388
 Chet. spirat. mp. m. F. b. 88
 feeti. ns. 1p. l. 415
 Ch. l. t. om. h. F. b. 63
 Crrhos. f. h. f. l. t. v. f. F. b. 56
 Cl. d. plast. um. t. f. h. os. l. t. Ap. l. 587
 f. w. u. d. April 39
 Cod. l. e. al. p. k. hro. os. m. l. Ap. l. 589
 Coll. p. th. rap. f. p. lm. r. t. b. lo. s. F. b. 277
 Co. d. m. l. l. f. rel. f. f. p. F. b. 164 16
 Cep. tu. l. d. f. tu. es. f. f. m. F. b. 103

D. ce. d. f. rm. ty. F. b. 263
 D. f. ti. h. m. l. Ap. l. 354
 D. l. f. l. rui. e. F. b. 61
 f. h. p. ng. al. Ap. l. 553
 f. l. prum. F. b. 60
 D. sa. ms. ril. April 336
 Dry. good. st. riliza. t. rma. l. April 344

Elb. w. rub. cul. is. April 56
 Emb. l. m. h. F. b. 04
 06
 Emboli. periph. ral. i. d. f. vira. ti. F. b. 0
 l. liza. f. l. l. F. b. 00
 01
 Emp. m. F. b. 8 April 416
 h. F. b. 94
 p. um. coecal. Ap. l. 418 419
 4
 Ea. ot. vns. h. et. rial. April 506
 E. st. my. F. b. 9 30
 Ep. ph. eal. p. ra. f. f. m. ral. h. d. treatm. F. b. 119

l. es. se. l. s. drom. April 616
 l. ns. b. l. Ap. l. 50
 l. et. April 467
 l. ky. ndrom. s. l. m. f. F. b. 56
 l. m. y. h. d. p. ph. l. sep. ra. n. F. b. 119
 h. f. d. fra. t. F. b. 103
 t. e. rs. sub. f. et. ns. Ap. l. 46
 os. m. via. supp. ra. Ap. l. 473
 F. rub. culos. Ap. l. 575
 F. rm. ld. h. d. d. f. et. Ap. l. 354
 Fra. in. mal. fi. n. d. l. d. se. d. ex. F. b. 84
 f. f. m. h. f. b. k. l. th. an. rpos. f. w. F. b. 108
 d. l. d. um. F. b. 109
 d. F. b. 109
 f. n. F. b. 253
 f. p. e. April 545
 d. cu. p. th. h. f. p. ph. f. m. t. l. pl. F. b. 83
 F. berg. en. Ap. l. 51
 F. ru. l. Ap. l. 399
 F. sob. et. a. April 51

G. le. es. Ap. l. 51
 Gangre. gas. Se. G. gangren. h. m. l. t. p. cu. Ap. 404
 m. Ap. l. 405
 Gas. ga. e. Ap. l. 407
 g. m. d. Ap. 381
 Ap. l. 510
 Gasse. ga. pl. l. h. l. m. F. b. 172
 G. str. Se. Som. b.
 Gastro. e. ro. st. my. f. p. p. l. f. m. F. b. 37
 G. h. d. se. pl. et. m. f. F. b. 35

P p st p ra p
 Ap 1 448
 Pl m nary b l F b 77
 80
 Plast g ry F b 253
 Pl es met l t h f ppl
 f tu F b 83 98 108 113
 Pl y pp ratu F b 287
 P m l mpv m Ap 1 418
 419
 P cum l v t pl l F b
 84
 pl ral F b 80 81
 b l F b 84
 P p p l F b 84
 P m h ra t f l p l
 m b l F b 80 281
 Pos p f Ap 1 331
 l dh p ex
 d g l tm t F b 7
 Pos et m ra h l h
 F b 135
 P b ruct d g F b
 135
 P p l mb v p pl
 m f F b 54
 P y g F b 99
 Ra b ry April 475
 R l g l h
 d m F b 233
 R f hyp p l v d m Ap 1
 6 l 630
 Ret g ss m f
 g m l F b 16
 Rl phy F b 19
 R b pp g p lm ry b
 l F b 84 86
 R g d gn f f tu
 d f rt b l segm
 Ap 1 533
 p ph l f p n April
 450
 lg g Ap 1
 601
 m f g g g Ap 1
 410
 R ll good d April
 340
 R p re f l p lpos F b
 196

S ose F b 6
 S ph throml d g
 F b 13
 S m f p ra m d
 April 541
 S l t y d m Ap 1
 611
 S ra ti pl t p
 F b 73
 S pl p Feb 20
 Sc t v lges
 April 606
 Se f l pl t F b 98 99
 108
 S p u f pp f m l p
 phy F b 119
 Septum l d l F b
 60
 Serum g ga g Ap 1 410
 Sh ld t h l Ap 1 576
 Sk f t Ap 1 399
 S l t nl t April 34
 Sp l d g ry l l th
 f F b 197
 h F b 179
 w h l m m F b
 196
 ts f f
 l f f p F b 175
 Sp d t m d Ap 1
 56 537 ff
 l n d l p ts April
 515
 rub loss Ap 1 569
 Spl m d pl y
 f F b 54
 Spl ts h d j n Ap 1 46
 464
 Spl m F b 43 54
 Spl m pl m f
 F b 55
 rt ry p l m ry lg tu
 pl m F b 49
 Sp dyl l h Ap 1 531
 S ph lococ al f u ns f k
 Ap 1 399
 t April 507
 S m nl za April 333 343
 S l h Ap 1 319 333
 S l f d gs ns ru
 m ts sutu es l ti et
 April 333

- V n -S rump l d ra f p
 Ap 1 544
 V B m y n, pp d t my
 b F b 1
 V d ast m f cu April 48
 V st es pau f l ra l es
 April 608
 V th rga m ds, April
 38
 V l pl t g pp d e
 t m b F b 1
 f t drai pe f p n eph b
 sees F b 156
 V s Se Iso N
 eptum d l cat F b 60
 V dling f pe l p F b
 15 154
 V rspt m n t ph loco cal
 f cu is April 403
 V n se uc x ra lges
 April 605
 V r anu ty p l l res
 Ap 1 548
 V os g l r l f of pau F b
 161
 V m pl ph rne l F b
 174
 rog us f rne m l n
 F b 16
 V h nd t u h ch stru
 m es F b 94
 tu F b 101
 Vose l f p F b 65
 l ga l t p F b 64
 fra tu es F b 253
 fresh, los d d F b
 255
 heal d d f rru es pe d
 F b 57
 h mp F b 64
 l f up d d F b 66
 d d l F l 6
 d t p F b 65
 V l p lpos ruptur f su
 g ry h jam F b
 196
 O gn, April 51
 Obstruct es l F b 19
 Ol och ra p lm ry tul
 los F b 60
 Operati g room f l m g
 o taminati n bi April 363 366
 37
 Operati d f cu f
 Ap 1 330
 m m g m f
 Ap 1 35
 Orr tr me f h
 m l April 586
 O rth f p ra m d
 Ap 1 546
 Os m k hro c April 581
 Ost m Bra k it d f d
 F b 13
 d hl dg d para f
 ppe f m ral p pl F l
 131
 subtr sch sep f
 pp f m ral p ph F l
 l 13
 P rel f osu gical F b 161
 rad u f Ap 1 601
 P l p f cu Ap 1 43
 46
 P h d gl d th rod
 F b 235
 P h d m Ap 1 633
 P ra trebral block f mp h
 h un asc l d d rs F b
 10
 P h m Maru b d F b 109
 P tr k gn April 51
 P dl Ap 1 35
 P p l g tr re f
 F b 40
 ga -e m f F b
 37
 g cal m m F b 31
 P re cul A rum f l
 b w lges 4p 1 604
 P l pp ra April
 43
 P j hri b es f b 149
 dra t F b 15
 P l pa dl g f F b
 153 154
 P m g l f
 April 437
 P n Ap 1 43
 ct re tm Ap 1 451
 b ct lgy 4p 1 44

T m rs f p l d m l	W d d t l f
<i>F b</i> 179	<i>Ap l</i> 3 6 377
U c p p S P pt l	<i>Ap l</i> 327
Ul b rs <i>Ap l</i> 475	C [D k t tm t <i>Ap l</i>
Uht l t d nf f	327 386
p r t g m h <i>Ap l</i>	h m th py <i>Ap l</i> 3 9 388
366 373	l d pl t t <i>Ap l</i>
U ls d za <i>Ap l</i> 341	39
h l g <i>Ap l</i> 377	
f t d <i>Ap l</i> 326	
p t f f <i>Ap l</i> 330	
m m g m f	
<i>Ap l</i> 357	
pp a g lf m d l lly	
<i>Ap l</i> 407	
t l t f <i>Ap l</i> 387	
W t b l <i>Ap l</i> 576	
/ d f t <i>Ap l</i> 355	
/ p d g g g	
<i>Ap l</i> 410	
g l f t 1p l	
48 497	
w d th py <i>April</i> 3 8	
391	
Z pl j f g l ca	
tra tu <i>F b</i> 275	

- S m h res cu f p p l
 hni F b 40
 S p cal ll li f h d
 April 469
 mp m Ap l 418 4
 f cu ist April 508
 supc fi l Ap l 404
 S p b an u d
 April 383
 S rump ll on April 51
 S b su f cu
 April 399
 S b h m F b i
 S lf d az Ap l 487
 S lf l m d April 483
 risc l an p red ct f
 f tu es F b 100
 p ti f p n Ap l
 449 41
 S lf p d Ap l 486
 S lf h l Ap l 486
 h ni m l Ap l
 593
 S lf m d drugs dosages Ap l
 487
 f ct rs su cess l m
 Ap l 489
 ga ga April 409
 h d f Ap l 440
 perica d April 433
 ph l al nf
 April 40
 p fi l st p ococ l
 f April 406
 surgical nfec April
 48 49
 raum d April 388
 m d f ctu n, Ap l 484
 rela surgical p occe res
 Ap l 490
 u ca ti Ap l 488
 S rg cal nf ns impos m
 April 31
 hni svmpo um n, F b 1
 S tu es sp al d surg ry F b
 191
 o-h d h h F b
 101
 st riliz Ap l 341
 S mp th n h n, para rt bral
 block scul diso d rs F b
 10
- T troo d l F b 71
 T hni sr nl Ap l 319 333
 su gical impos m n, F b 1
 T n supp u f h d
 April 473
 T ra Ap l 38 411
 es sta ce t April 509
 t d p phyl
 Ap l 411 41
 Th na pa bsc Ap l 44
 46
 Th mas pl nu d fractu
 f f m F b 105
 Th ra pl uy vtrapl l p l
 m ry tub l n, F b 83
 Th mbect my F b 06 07
 Th mbocyt pe p rp ra spl
 ct m f F b 54
 Th mbosis d p f l
 l F b 214
 ph asce d F b 13
 Thy d ct m cel F b 1
 T lf ct m h F b 37
 d g l hes F b
 40
 d local thes F b
 49
 T ds, re f m l
 F b 5
 Transfus d p rem q
 m tr F b 300
 Tra f post pera spl
 m F b 59
 p cop ra spl m
 F b 57
 cu F b 97 108
 hni F b 297 304
 rsal d es F b 310
 Tra su hral prost es
 hni F b 135
 T genu al rv alcoh l jec n.
 F b 171 17
 xposure F b 164
 pe ph ral d ns secu f
 F b 10
 trogassen m F b
 16 16
 T be lox f bo es d j
 Ap l 565
 f sp April 569
 p lm ry ll pse h py F b

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